NOV 27 1931

THE DECEMBER SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

MICHAEL FARADAY. Sir William H. Bragg 481

JAMES CLERK MAXWELL. Dr. Edwin H. Hall 500

A RETROSPECT OF WIRELESS COMMUNICATION. Sir Oliver Lodge 512

CHILDHOOD IN THE MACHINE AGE. Dr. Lawrence Augustus Averill 522

SAVE OUR WILD FLOWERS. Professor Edgar T. Wherry 535

A MODERN EDUCATIONAL PLANT. T. Swann Harding 539

SCIENTIFIC EMINENCE AND CHURCH MEMBERSHIP. Dr. Harvey C. Lehman and Dr. Paul A. Witty 544

SCIENCE SERVICE RADIO TALKS:

WHAT THE ATOM LOOKS LIKE. Dr. A. H. Compton 550

THE DISTANCES OF OUR NEARER STARS. Dr. John A. Miller 552

MAN'S CONTROL OF HIS OWN DEVELOPMENT. Dr. Oscar Riddle 555

THE LOCOMOTION OF THE SLUG. Dr. H. A. Allard 559

THE MOUSE-EATING TARANTULA. Phil Rau 563

THE PROGRESS OF SCIENCE:

Henry Burchard Fine and the Fine Memorial Hall; Presentation of Medals by the American Institute of Mining and Metallurgical Engineers; Samuel Wesley Stratton; The Award of the Research Corporation Prizes 565

INDEX 575

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THE SCIENTIFIC MONTHLY

DECEMBER, 1931

MICHAEL FARADAY[1]

By Sir WILLIAM H. BRAGG, K.B.E., F.R.S., D.C.L.
DIRECTOR OF THE ROYAL INSTITUTION OF GREAT BRITAIN

I AM to speak to you to-night of Michael Faraday, of whom we shall hear much during the coming year. For he was one of the greatest experimental philosophers that ever appeared in this country or indeed in all the world; and of his discoveries none has had more consequences than that which he made in 1831, a hundred years ago. It was then that he found the true relation between magnetism and electricity. On this relation and on others, which he discovered in a few following years of intense thought and labor, have been founded all those applications of electricity which form the muscles and nerves of our modern life. How many and great these are we may realize if we think of the consequences of stopping every electric current that is running at this moment, so that we bring to an end all electric distribution of light and power, all transmission of news by telegraph and telephone, and a hundred other uses of electricity on which we have learned to rely. The very means by which I am addressing you to-night, the microphone that stands before me, the machine that transfers its vibrations to the ether, the receiver and the loud speaker which are beside you, are all constructed on principles first enunciated by Faraday; the whole mechanism and conception of broadcasting can be traced back directly to his work. Very few men have changed the face of the world as Faraday has done.

The most striking of his discoveries was made in 1831, and since it has led to the development of the electrical industries of every kind, electrical engineers of all countries are joining in centenary celebrations, of which the principal is to be held in London in September, next. The most public feature will be the fourteen days' exhibition which is to be held in the Albert Hall, beginning on September 23. It is to be arranged conjointly by the Royal Institution, where Faraday lived and worked, and by the Institution of Electrical Engineers, the latter body generously supplying the necessary funds. And since other discoveries of Faraday have been the foundation of some of our greatest chemical industries, English chemists are also taking their share of the enterprise and of the cost.

OUR DEBT TO FARADAY

This display will emphasize the great industrial consequences of Faraday's researches. Yet if I am to keep matters in their true proportion, I must at once add other reasons for the general wish to acknowledge our debt to Faraday. Though he described himself as being

[1] A Broadcast National Lecture delivered on March 4, 1931, under the auspices of the British Broadcasting Company.

MICHAEL FARADAY

A STATUE BY FOLEY IN THE ENTRANCE HALL OF THE ROYAL INSTITUTION.

nothing else than an experimental philosopher it came about as a necessary consequence of his experiments that he modified profoundly the basic principles of scientific thought. He not only laid the foundation of some of the greatest and most successful of our industries, he also drew from his experiments clear-cut deductions which have made modern science possible and have led towards the strange and fascinating concepts of the physics of to-day. He has modified not only our mode of life but also our ways of thinking.

Yet another cause of our admiration lies in the extraordinary affection with which he is still regarded. Presumably this is a survival of the feelings of his contemporaries: how strong that must have been is evidenced by its persistence. During the last few months of preliminary preparation for the coming centenary it has been a constant surprise to find that every one interested in science, in other countries as well as in this, entered gladly into the spirit of the proposals, not only because the significance of Faraday's work is well understood, but also because the memory of the man himself still has its charm.

And now I must speak rather more particularly of his life and his work: I must describe the nature of his discoveries in broad outline and I must try to sketch the man himself. I hope I may be able to show you how proud we have the right to be of this countryman of ours and how the spirit in which he set about his work was that before which difficulties always tend to disappear; how he was just the man whose example can be the greatest encouragement in the difficult times through which we are passing.

Early Years

Faraday began his working life in 1804, being then thirteen years old, as an errand boy to a Mr. Riebau, a newspaper agent and bookbinder in Blandford Street, near Manchester Square, London. It was his duty to carry round the news sheet of the day to the various subscribers in turn, giving to each person the time allotted for his reading of it. Faraday is said to have had a tender spot for newspaper boys ever afterwards. A year later he was bound to Mr. Riebau as an apprentice. Professor Tyndall relates that, many years afterwards, Faraday pointed out to him, in the course of a walk which they took together, the spot in the shop where he used to work at his bookbinding. Until quite lately the shop front was still in existence.

The handling of the books gave Faraday opportunities to read which otherwise could never have been his. Until he thus began to teach himself, he had had but the scantiest instruction in arithmetic and grammar. He made his bench his school; and it is very interesting to see what he learned there. Picture the boy, with an acute mind absorbed in the acquirement of knowledge and ill-furnished with it at the outset, gathering all that he could from the volumes that passed through the bookbinder's shop. Some of them were scientific works in which he took the deepest interest. He himself says that he delighted particularly in Marcet's "Conversations in Chemistry"; that Watts' "On the Mind" first made him think, and that his attention was turned to science by the article "Electricity," in an encyclopedia which he was employed to bind.

It is easy to imagine that the beauty of Faraday's style of writing, its clearness, strength and rhythm, were due to the literature which he encountered in this way, and attempted to copy. In all the books that he read he would meet with little that did not conform to the mature style of that day; there was no light literature of the modern kind. It is not surprising to find that the copious

MICHAEL FARADAY AND HIS WIFE

letters which the self-taught young man wrote to his friends seem to emulate the polished and balanced sentences of the *Spectator* or "The Vicar of Wakefield." Take the following from a letter to his friend Abbott, written when he was twenty:

> Let me notice, before I cease from praising and recommending epistolary correspondence, that the great Dr. Isaac Watts (great in all the methods respecting the attainment of learning) recommends it as a very effectual method of improving the mind of the person who writes and the person who receives. Not to forget, too, another strong instance in favour of the practice, I will merely call to your mind the correspondence that passed between Lord Chesterfield and his son. In general, I do not approve of the moral tendency of Lord Chesterfield's letters, but I heartily agree with him respecting the utility of a written correspondence. It, like many other good things, can be made to suffer an abuse, but that is no effectual argument against its good effects.

Finding His Way through

It would not be fair to find fault with the apparent sententiousness of such a passage as this. Faraday was in the absorbent stage and had made great use of his opportunities, drinking in knowledge and ideas from every source available to him. When in later years he had to explain to the world the results of his own experiments, and the deductions which he made from them, the first heaviness disappeared. His writings became models of good and restrained expression, which kept all the qualities he had admired in his youth: every lover of science knows their charm.

Davy's Influence

In 1812 came an opportunity of attending a course of lectures given by Sir Humphry Davy at the Royal Institution. Sir Humphry was then at the height of his fame as a chemist and a lecturer, and his discourses were social events. Faraday took copious notes of a set of lectures on chemistry, one of them on chlorine. This remarkable gas had only recently been isolated and was one of the scientific wonders of the day. Faraday made a fair copy of his notes and bound the beautifully written pages into a volume which he sent to Davy. This book is now one of the greatest treasures in the Royal Institution. Davy was much pleased, but when asked by Faraday if there were any vacant post at the institution he could only say no, for, however he might have liked Faraday as an assistant, the institution was much too poor to find wages for him. It happened, however, not long afterwards that Davy found grave fault with his only laboratory servant and dismissed him on the spot. As the result a carriage and pair invaded Weymouth Street, where Faraday then lodged. A footman descended and took in a note to "Mr. Faraday," which resulted in his engagement next day as assistant to Davy at 25 shillings a week with two rooms in the institution. This was the beginning of Faraday's scientific career. In the quiet laboratories in the basement of the Royal Institution he helped Davy to continue his chemical investigations.

A great experience awaited him in October of the same year, 1813. Sir Humphry and Lady Davy went on the grand tour of Europe, which was to last for a year and a half and to take in some of the greatest sights and the finest scenery on the Continent. Moreover, to the great contentment of Faraday, who went as assistant and amanuensis, visits were to be paid to many of the famous laboratories. In Paris, Davy and Faraday studied with immense interest the new substance, iodine; in Florence they burnt diamonds by means of the concentrated rays of the sun in the laboratory of the Grand Duke; at Rome they were shown experiments on magnetism; at Geneva, on the heat of the sun's invisible rays.

Faraday was a great letter writer, principally to his mother and his young friends, so that the events of the journey are well and fully recorded. So also is the joy of the home-coming in 1815. Once more the pair settled down to steady work at the Royal Institution; but as the years went by Faraday took a greater and greater share of it and, when Davy died in 1829, Faraday was appointed director of the laboratories and all the responsibilities for the work of the Royal Institution devolved upon him.

I must refer to two famous pieces of work which belong to these years. The first, in 1823, was the condensation of chlorine into a liquid, one of the early events in the story of the liquefaction of gases now so great a matter both in pure science and in industry. The story goes that Faraday was experimenting with chlorine and had sealed up a portion of the substance in its usual gaseous state, confining it in a closed glass tube. It happened that a very high pressure had been reached in the process. A little of the gas condensed and formed a patch of oily liquid within the tube. An interested visitor to the laboratory remarked that the tube must be dirty, a friendly insult which had to be washed out by a thorough examination of the circumstances. Next day Faraday was able to say that the oily liquid was condensed chlorine. Several other gases were similarly liquefied, but the more difficult gases—oxygen, nitrogen, hydrogen—were beyond the means available at that time. Though Faraday subsequently discovered that chlorine had already been liquefied by Northsmore in 1805, a fact which he hastened to acknowledge, yet his own researches on this subject were of great importance. The work was a notable contribution to the knowledge of a subject which is of high theoretical value and is the main principle of the refrigerating industries.

The other discovery of this period was that of benzene. It was then the custom to supply illuminating gas under compression in iron cylinders. Faraday's brother was actually one of the men engaged in the house-to-house delivery and collection. The cylinders returned as empty contained a small quantity of a fluid which Faraday examined. From it he isolated a substance of which he determined the constitution to be, by weight, twelve parts of carbon to one of hydrogen. He named it bicarburet of hydrogen: we now call it benzene. A little of the first liquid which he thus obtained is still preserved in the Royal Institution. Now, as is well known to many, this substance is the basis of half organic chemistry, and in particular of modern dyes. Faraday did not, it is true, make these dyes, nor did he come to a knowledge of those further developments and processes, due to the great organic chemists of the nineteenth century, which finally led to the establishment of the dye industry. But Faraday's part of the work is gratefully recognized by chemists as that of their pioneer. On the centenary of the discovery of benzene six years ago, a large meeting was held in order to record their debt. Perhaps the most striking way by which to draw general attention to the greatness of this work is to point to the recent excited discussion over the renewal of the dyestuffs act, of which it may justly be said that the point at issue was whether or no it was for the good of the country that our people should be given favored opportunities for the manufacture of the products derived from Faraday's bicarburet of hydrogen.

Experiments with Electricity

Now we come to the famous electrical discoveries made in the half dozen years of which 1831 was the first. Let me try to explain their significance.

The first of these discoveries gave us the means by which, in these days, we produce electric currents. There is no need to enlarge on the extent to which the electric current is used in modern life. But in those days electricity was a philosopher's toy. Even the curious experimenter who wished to generate electricity must employ the cumbersome old machines in which charges were developed by rubbing plates or cylinders of glass, or he must make use of the expensive primary batteries consisting of metals acted upon by acids. There was no such thing as insulated wire to be bought: it had to be made in rough and ready ways in the laboratory.

Now there had for some time been prevalent an idea that it might be possible to generate electric currents, by means of what men called induction. The principle was simple enough. A magnet, as was well known, transformed any neighboring piece of iron into at least a temporary magnet, though the iron had previously shown no traces of being magnetic until the primary magnet "induced" it to become one. The induced magnetism persisted in the iron as long as the proximity was maintained. So also an electrified metal sphere "induced" charges upon any neighboring metal sphere, though the latter might be previously uncharged. Again the induced charge persisted so long as the spheres were neighbors. Then, it was asked, might it not be expected by analogy that if a wire along which a current ran steadily in one direction lay alongside another wire which was capable of carrying a current, induction would cause a current to run in the second wire so long as it ran in the first? We may be sure the effect was often looked for. It is easy to say now that, of course, nothing of the sort should happen. Faraday himself made many electromagnetic experiments without hitting on the truth. But on August 29, 1831, he made the great discovery, which is so simple that it does not seem possible to make the telling of it dramatic. The same difficulty stands before us in the matter of the Centenary Exhibition at the Albert Hall. We are to have a statue of Faraday in the center with his first apparatus about his feet while the fruits of his experiments line the walls and the connecting links run between like the spokes of a wheel. But when we make up the old experiments or take down the original pieces of apparatus, if we have them, from the cases where they are carefully preserved, the few pieces of wire and tape and string and iron look so insignificant that we might become afraid. Surely, however, those who see these little things will ponder on their meaning and give us that imagination without which any effort to kindle enthusiasm is like putting a match to an empty grate.

A Simple Experiment—

When Faraday, on August 29, 1831, tried the experiment of electric current induction as others besides himself had tried before, but now by a new and most aptly devised method, he found that the expected induction was there but not quite in the expected form. A current ran in the second wire, while the current was being started in the first: as soon as the current in the first wire reached its full strength and became steady there was no further current in the second. But when the current of the first wire was being stopped there was again a current in the second which ran until the stopping was over. In other words, a steady current has not the power to induce. It is only a changing current that can do it, and that is the whole story. By subsequent experiments Faraday widened and clarified his first ideas. He soon made it clear that it was equally effective if the position of the first wire was undergoing change while its current remained steady, or if again a magnet were brought near the second

MICHAEL FARADAY

AT THIRTY NINE YEARS OF AGE. A PORTRAIT PAINTED BY H. W. PICKERSGILL.

wire; because all these different actions were but variants of one, namely, an alteration of the magnetic conditions in the space near the second wire. In Faraday's mind the space about a magnet, whether a permanent steel magnet or an electromagnet such as he wound in numbers for himself, using his home-prepared wire, was in some way affected, so that it was abnormal: and he imagined that this state varied in intensity from point to point. He was very curious about this condition: he scattered iron filings over a sheet of paper lying over the magnet and watched them as they arranged themselves in elegant lines, thinking so to come to some ideas about that condition, just as the marks on the sand may show which way the tide has run. These material lines were to him the visible signs of "lines of force" in space, as he called them, and as electricians have called them ever since. So we may make the great statement in yet another simple and comprehensive way. As long as there is change proceeding in the magnetic conditions of any space there will be a tendency for currents to run in a conductor embedded in that space. It is necessary to say tendency, for, of course, the conducting circuit might not be complete, so that no current could get round it, however great the tendency might be.

So if we move magnets past coils of wire we have the dynamo: and if we send electric currents alternately in opposite ways round one coil of wire we may generate alternating currents in neighboring coils and we have the transformer; and so the whole family of electromagnetic devices. That is all. It is a very simple conception on which to build so greatly.

—And Its Consequences

But there is even more in this than the foundation of industries employing millions of men. For here begins one of those great sweeps of thought that form the winding road by which research makes its way into the unknown. Faraday had conceived the idea that the space about the magnet was the seat of the working of those laws whose effects his experiments revealed to him. The iron and the copper wire were to him no longer the repositories of the powers whose actions he observed. These lay in the invisible tenuous space of which the materials in use might be considered to be the boundaries. He drew away from the older idea that magnets acted on one another across a space which was not concerned in the action. He began to think that on the contrary this space or a medium which filled it was the real seat of power. It was a breakaway from the material to the immaterial. The idea has been extraordinarily fruitful, first in Faraday's hands and then in the hands of Clerk Maxwell and other great men who followed him. It is true that the road has turned other corners since then. But what Faraday did has still its immense consequences, not only on the practice but also on the thought of our own times.

The wish to make these things clearer to himself was one of the reasons that prompted him to undertake a second set of experiments of fundamental importance. These related to the mutual attractions and repulsions of electrified bodies. He wanted to know whether in this case also the medium played a principal part. A conductor could be charged with electricity. What did charging mean, and where was the electricity? Was it on the surface, or was it distributed through the interior or was it partly outside and partly inside? There were appearances that suggested the importance of surfaces generally. Would it be good, therefore, to pack a hollow globe with a quantity of tin foil, which certainly had plenty of surface? Such a globe might more readily receive

a charge of electricity when the tin foil was there than when it was not. Comparison might be made with the effect of filling the globe with water. But he found no such differences. He tried a great number of experiments of this kind. In some of them he used a large boiler which he had obtained from the coppersmith's. He mounted it on insulating supports and charged it with electricity. He then tried to find what proportion of the charge was to be found within. His final experiment, made on January 15, 1836, was the construction of a great cube with an edge of 12 feet, made of a light framework, over which he stretched a covering lined with conducting material. It was set up in the theater of the Royal Institution and blocked up the center to the level of the gallery. It rested on insulating supports so that when connected with an electrostatic machine it could be charged with electricity until sparks flew from it and brushes glowed at every outside corner and projection. Faraday was inside the cube while this was going on and was in perfect electrical peace: his most delicate detectors of electricity showed no sign of disturbance.

This was the climax of a series of experiments which answered for him his question. The power that is displayed in the attractions and repulsions of electrified bodies or in the electric spark does not lie in those bodies. It is seated in the surrounding space, of which the bodies may be regarded as boundaries: he had held a similar belief as regards magnetic effects. That is why nothing electrical happens inside an electrified conductor. That is why Faraday could sit peacefully inside his cube while electrical storms raged outside. His case was a perfect lightning conductor or rather protector from lightning. His experiment showed that energy could be stored in the space between two conductors differently charged with electricity. This is the principle of the so-called (and very badly called) condenser. How important this discovery has been every electrical engineer knows well, whether he deals with the distribution of alternating currents or with submarine cables, or wireless, or, indeed, with the majority of the applications of electricity.

Now it may be argued that Faraday's experiments can nowadays be interpreted in different terms. That is not of the least consequence. Faraday's interpretations were a new presentation of the whole matter, illuminating and fruitful in the highest degree. What he saw and put into his own language is there still, and will be there for all time. Faraday's mode of thought supposed the existence of a space-filling medium which could be the seat of his magnetic and electric forces. We speak of this medium as the "ether." Clerk Maxwell, whose centenary is to be celebrated at Cambridge this year, showed that the ether which Faraday described so as to satisfy his experiments must be able to carry waves, and he framed the famous hypothesis that light itself was simply an electromagnetic disturbance traveling through the ether as a wave travels over the surface of the sea; or a sound wave through the air. We are using such ether waves at this moment. The ether of Faraday and Maxwell is as useful as ever, even though there are newer and bolder flights of thought which express themselves without it.

Arguing from Unity

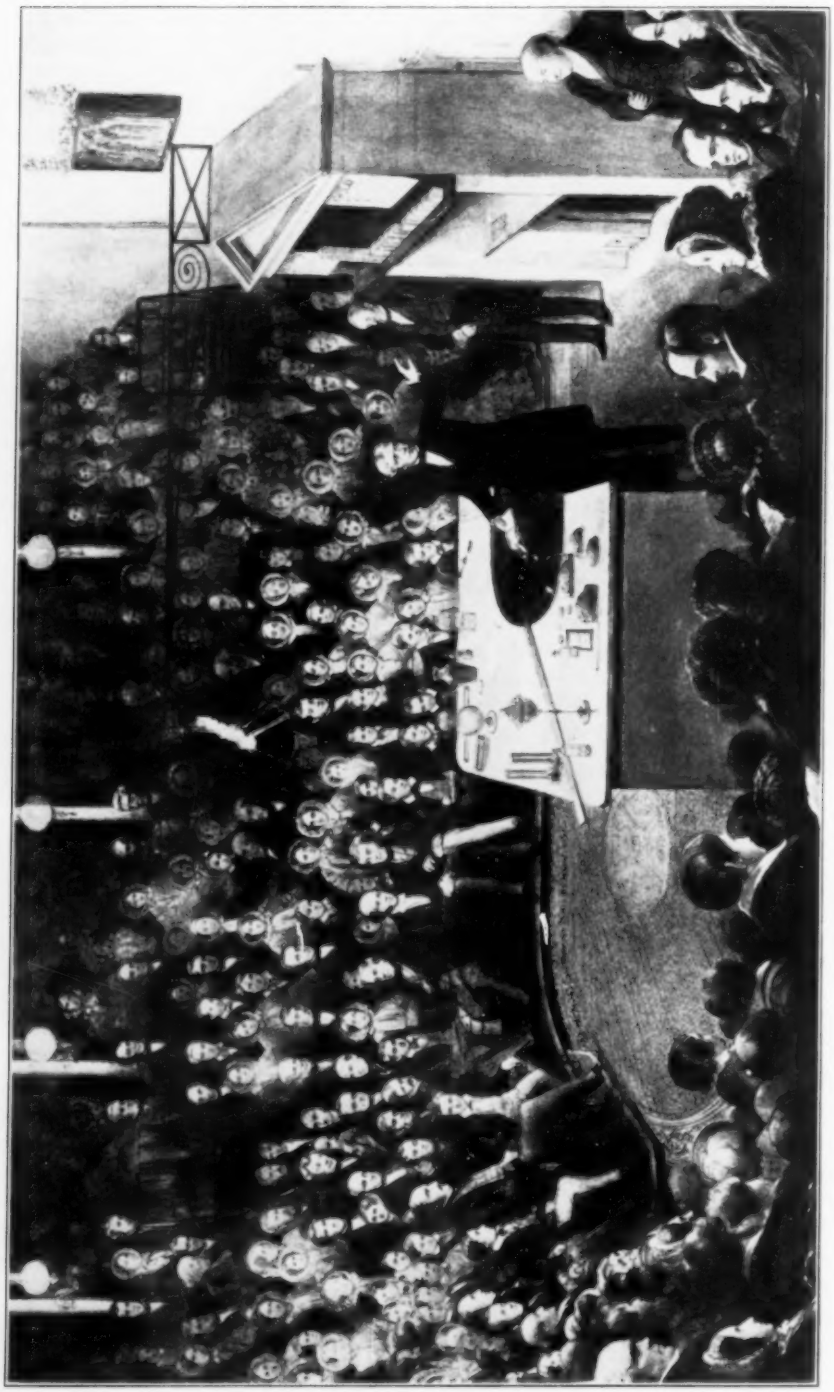
Thus Faraday threw all magnetic and electric actions into his medium. It would not appear to him that confusion might be introduced by doing so, and Maxwell's development of his ideas was their justification. We shall better understand his thought in this respect, and, indeed, the whole movement of his mind, if we consider the vision that urged him forward. He had a fundamental belief in the unity of nature's

manifestations. Light, heat, magnetism, electricity, chemical action, gravity, cohesion and so on, must somehow, he thought, be interconnected. Many such mutual relations were, of course, known in Faraday's day: heat, for example, could influence chemical action. But Faraday had more in his mind than the existence of a limited series of separate links. In pagan days men raised up a little god to rule independently over every separate manifestation of nature —sunshine and wind and rain, lightning and thunder. As thought broadened the little powers became aspects of a greater majesty. The world became one kingdom. To Faraday it seemed that the laws of such a kingdom must bear a common impress and be interwoven in their effects. Whatever electricity was, or sunshine, or chemical action, surely their operations could not be independent; electricity, for example, must be connected with magnetism, with chemistry, with gravity and so on. To look for the connections must be a fundamental inquiry. Indeed, it would not be wrong to sum up the greater part of Faraday's scientific activities as an endeavor to join all nature's manifestations together, to bind the parts into one great whole. It was in this spirit that he hacked his way through endless labors and dull details so often to emerge triumphant at last. Sometimes he failed where others have succeeded in later years.

These two great experiments that I have described, the first on the generation of current by magnetic induction, the second on the seat of electrostatic force, were the important members of a long series by which Faraday worked out the laws that govern the construction of electric devices. They may be said to be represented by the two quantities, inductance and capacity, which are the chief immaterial contents of the wireless set. Their relative adjustment constitutes "tuning in." And that which is thus made capable of reception is the "wave" which Maxwell described in precise detail as following necessarily on Faraday's work. But, of course, the wireless set is very far indeed from being the solitary example of the application of Faraday's principles.

In the Scientist's Laboratory

I should like to tell you very briefly of another research. I have said that Faraday put before himself as a main purpose the discovery of the connection, which he believed to exist, between every pair of the manifest forces of nature. He tried in 1845 to find some connection between magnetism and light, to find whether a light-ray could be affected in any way by his lines of electric or magnetic force. Imagine him standing in his quiet laboratory on the morning of September 13, 1845. He has already been at work for several days searching for any effect of electricity on light. He has filled many pages of his diary, but always at the end of the short description of each experiment he has been obliged to write "No effect." To-day he will try whether magnetism will serve him better. For magnetism he has magnets at his disposal, and for light there is daylight coming in through the windows and he can produce artificial light if he requires it. What shall he do first? Shall he allow a strong beam of light to fall on a piece of iron and then magnetize the iron in the hope that some change will appear in the light or the iron? He may try, but his means of observation are not powerful enough to give him a result. He goes about the matter in a more sensible way. If there is an effect which nobody in the world has ever seen before, it surely requires favorable circumstances and delicate observation. He will therefore use his great electromagnet, the strongest that he has. If light is to be affected, the quality or condition of the light which



FARADAY IN THE LECTURE THEATER OF THE ROYAL INSTITUTION

DELIVERING ONE OF THE CHRISTMAS JUVENILE LECTURES ON METALS.

he is most likely to watch with success must surely be one in which it is easy to detect change. Now there is one in which such detection is extremely easy. He must use polarized light: that is to say, light in which the ether vibrations are not taking place in every possible direction perpendicular to the ray, as they are usually, but are confined to one such direction indicated by what is known as the plane of polarization. The early years of the nineteenth century had been full of investigations of light in its polarized form. At the Royal Institution itself, Thomas Young, one of the foremost thinkers in the subject, had taught and worked. Polarized light is common enough in nature, as, for example, the light from the sky; and the physicist can produce it in various ways at will. Faraday produces such a ray of polarized light and adjusts his instruments to the determination of the plane of polarization, an observation which can be made with great accuracy. He makes his ray skim the surfaces of his magnet poles and turns on the current that makes the poles active. There is no result. He enters the fact carefully in the diary. He rearranges his poles, alters his ray, makes it traverse various transparent substances while near the poles, and in many ways he looks for an arrangement which will show him what he seeks. For some time the day is no more successful than the days that have gone before. What could have kept him to his patient search but conviction that it was reasonable to hope for a result? And if one should appear he would see for the first time a vision of one of the great laws of the universe. He was well aware of the significance of his search.

A Triumphant Entry

And then there *is* a result. A particular arrangement of the magnet, a particular adjustment of the light, a special piece of glass through which the light has to go: it is a heavy glass taken from a batch prepared while working at glass under a government commission. And when he turns the current on to the magnet the plane of polarization moves, a glimmer of light appears in the optical arrangement which has been adjusted to darkness when the electric current was off. It is delightful to see in the diary the expression of his joy. "But," in capital letters underlined, "when . . . such and such arrangements were made . . . there was an effect produced on the polarized ray and thus magnetic force and light were proved to have relations to each other." There is in this case no outstanding industrial development of his new discovery, but it was to him, and is to us, another of the links that bind nature's forces into one.

His attempts to connect gravitation with electricity or heat are of the same character: their interest is none the less because they failed completely. Faraday leaves us a record of his feelings as he entered the empty lecture theater from the high roof of which he intended to drop coils of wire which might possibly be found to be carrying currents on their way down. "It was almost with a feeling of awe . . ." he writes at the beginning of the note in his diary. It happened, curiously enough, that for many days he believed he had found what he looked for: but his effect was spurious. Indeed, it was impossible that he should be successful. It was not until Einstein had developed his theory of relativity and the astronomers had carefully measured up their observations of the eclipse in Brazil that a true effect was found. Then it was clear that the ray from a star had been *bent* by going close to the sun. Electromagnetic waves had been turned aside by the gravitational forces of the sun's mass. Gravity and light were linked together.

THE ROYAL INSTITUTION IN LONDON

WHERE FARADAY DISCOVERED THE RELATION BETWEEN MAGNETISM AND ELECTRICITY.

Faraday could never have found any such effect, though he was sure that something was there to be found and returned often to the search for it.

I have now said enough, I believe, to give an idea of the nature of the problems which Faraday attacked, and of his reasonings and methods, though I have referred only to a very few of the things which he did. I have said nothing, for example, of his tremendously important work on the connection between electricity and chemistry. This work may be described as having established the atomic theory of electricity and, indeed, as having foreshadowed the electron. It laid down the laws of electrolytic action and made a notable addition to the chemical knowledge of the atom and the molecule. It is the basis of some of the most important electrochemical industries of modern time.

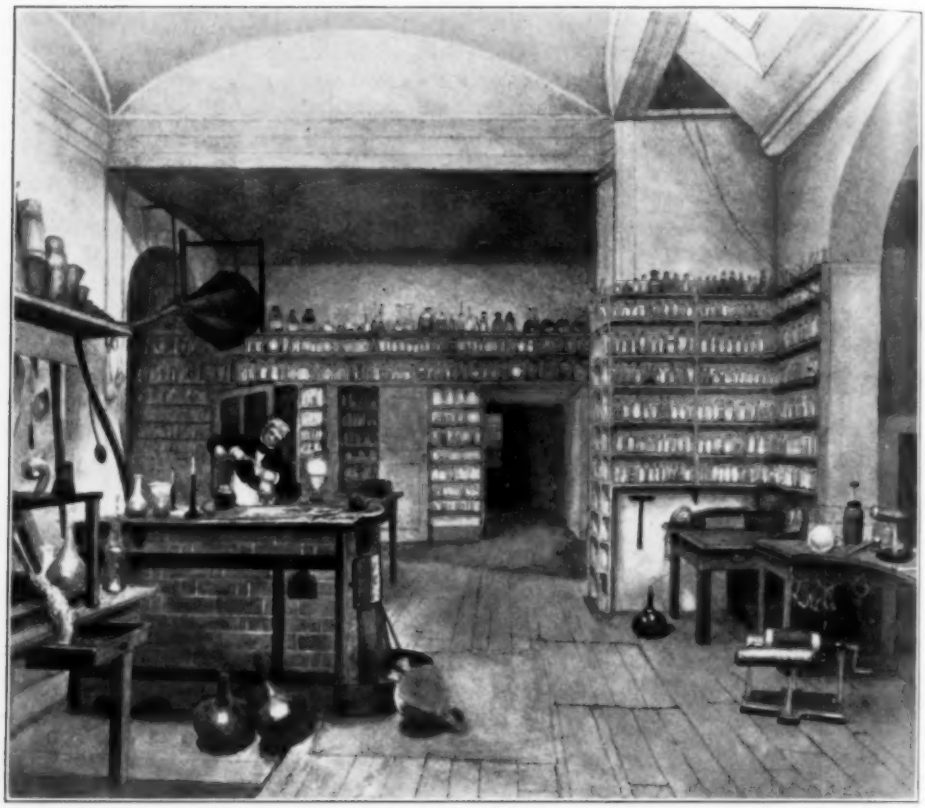
The Lecturer and Man

When the knowledge of Faraday's work became general in the scientific circles of Europe, principally through his publications in the journals of the Royal Society, and when its value came to be perceived, he became a notable figure. But at home he had yet another mode of entry into men's regard. He lectured in the theater of the Royal Institution with such clearness and power, such simplicity and charm, that tradition, now speaking but rarely at first hand, still passes on the most reverent and affectionate memories. The courses of lectures which he gave so often at Christmas, nineteen times in all, to "Members of a juvenile auditory," as the old phrase has it, would alone have made him and the Royal Institution famous. Sir Alfred Yarrow, the famous shipbuilder, one of the few now living who went to his lectures, has told me how he and his boy friends so loved a word with the old man that they used to waylay him on Sunday on his way to church. And having benefited by one lot of kindly greetings they would let him walk on, but themselves run by back streets to intercept him again.

He took a great and helpful interest in the scientific affairs of the nation. Even in his earlier days his reputation as an experimenter and thinker brought to him many who wanted his help and advice. He could indeed have built up a lucrative consulting practice, but refrained because he wanted his time and energies for his researches. His decision was marked by a drop in his income from fees, from over £1,100 in one year to £160 in the next. But he responded generously to suggestions that he should place his scientific abilities at the service of the state. There was in the eighteen-twenties no little anxiety as to the state of the glass industry, particularly in respect to glass of high quality. Faraday formed one of a small working committee set up to make experiments. They worked first in Camberwell, but subsequently a glass furnace was built for Faraday in the Royal Institution. Very interesting work was done, though nothing emerged of immediate practical application. Some remarkable glasses were made and the whole labor and cost were indeed covered by the striking use which Faraday was able to make of some of the glasses in his subsequent researches. I have already spoken of one of them.

Service to the State

Faraday was consulted by the government in respect to mining dangers, and was indeed one of the first to point out the explosive character of suspensions of coal dust in the air. But his most extensive and continuous service to the state was rendered as scientific adviser to the Trinity House, which post he occupied during the greater part of his life. This body takes charge of the lighthouses. It is interesting to observe



FARADAY AT WORK

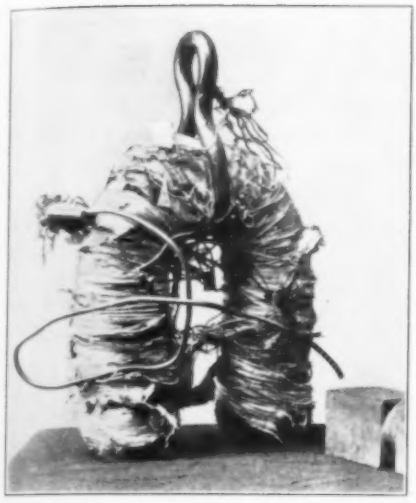
IN HIS OLD LABORATORY AT THE ROYAL INSTITUTION. FROM A CONTEMPORARY WATER COLOR.

that he saw the gradual replacement of the old oil-burning lanterns by the electric machinery which he himself had made possible. He appears, however, to have been very cautious in the matter, and to have asked for exhaustive trials rather than to have pressed impatiently for progress. Even when he was over seventy he was still making trips by sea in order that he might have the material for his reports. For this work he received a certain pay, but it was extremely moderate in amount, perhaps because he himself did not ask for more. He writes to the deputy master of Trinity House:

> In consequence of the goodwill and confidence of all around me, I can at any moment convert my time into money, but I do not require more of the latter than is sufficient for necessary purposes. The sum, therefore, of £200 is quite enough in itself, but not if it is to be the indicator of the character of the appointment; but I think you do not view it so, and that you and I understand each other in that respect.

He certainly received at no time a worthy pay from the managers of the Royal Institution. On July 4, 1853, when he had been at the Royal Institution for forty years, the managers report to the general meeting that

> They have advanced the salary of Dr. Faraday from £100 to £300 per annum. . . . The financial condition to which the Institution was long reduced by these various disasters restrained former Committees of Managers from offering to Dr. Faraday that consistent remu-



FARADAY'S "GREAT" ELECTROMAGNET

neration which, as they were well aware, his intimate acquaintance with the state of the Institution would have then withheld him from accepting. But the effects of these disasters have now passed away, and the prosperity of the Institution is as permanently secured as is compatible with the condition of a society depending on public estimation. The Managers therefore now feel themselves fully justified in awarding to Dr. Faraday the only remuneration which it is in their power to bestow.

Thus Faraday grew not only to be a great figure in scientific circles but also to be a valued public servant. He may even be said to have been a figure in society life of the day. He was the first secretary of the Athenaeum Club. But his relations to society were one-sided. His discourses at the Royal Institution drew hearers of every class: the Prince Consort himself was a frequent attendant. He certainly admired Faraday himself, and we may well believe that he considered Faraday's work and influence to be of high value to the nation. But though society came to Faraday, Faraday did not go into society. This was not because he was unsociable. On the contrary, he was full of fun. I wonder what the staid managers of the Royal Institution thought of the parties when velocipedes were ridden round the corridors of the theater. His abstention from all society engagements except the meetings with a few intimate friends was due simply to the decision that he must concentrate on his principal work.

It would be absurd to think of these renunciations of money and social pleasures as marks of a foolish quixotism or an unhappy nature. From all such perversions Faraday was poles apart. He knew perfectly well what he was about. He was thoroughly happy in his work, which filled his mind with great visions. And he was just as happy in his private life, of which it is necessary that I should say something. If he had not been so content he could not have given his hearers so much delight and encouragement. *Punch* may have rallied him for his lack of a certain ambition:

Oh, Mr. Faraday, simple Mr. Faraday!
Did you of enlightenment consider this an age?

THE HISTORIC RING OF SOFT IRON

WOUND WITH SEPARATE COILS OF COPPER WIRE CONNECTED TO BATTERY AND GALVANOMETER, RESPECTIVELY, USED BY FARADAY IN HIS FIRST SUCCESSFUL EXPERIMENT IN ELECTRO-MAGNETIC INDUCTION.

Bless your simplicity, deep in electricity,
But in social matters, unsophisticated sage!

—but the lines were surely written with a very kind smile and very deep respect. Of all the words in the English language the word "simplicity" has variations of meaning which differ most from one another: the simplicity of Faraday was of the kind which brings the other virtues in its train.

A chief contributor to the happiness of his private life was the wife whom he married as Sarah Bernard in 1821, when he was thirty. He was devoted to her. She does not appear to have demanded more than he gave her, or was able to give her in the mode of life which he chose. She must have satisfied him completely, because whenever he was away from her he wrote in terms that show how he turned to her; and when he passed through the long periods of overstrain which his eagerness brought upon him, she was his constant and beloved companion. There were no children.

The only recurrent complaints that appear in Faraday's letters to his friends are in respect to his loss of memory and oppression by headaches. No doubt the burning excitement of his researches made him too little aware of bodily exhaustion. After the period of the first great electrical researches in 1831 to 1840 a long rest was necessary: and when in 1845 he tried to begin again he found he was hampered by inability to concentrate. Nevertheless, there were still great times before him. Only, as he grew older the bursts of activity became shorter and the necessary resting time longer. Wilhelm Ostwald, who has recently written a most interesting psychological study of Faraday, believes that it was his inability to trust his memory that led him to write his well-known diary, his day-by-day record of his work and deliberations and proposals for the future, interspersed with occasionally delightful little touches of jubilation or resigned disappointment. He began, however, to write his diary in his early days, when there was no evidence of distress, and the careful style changes very little as the years go by. Although his letters show that the loss of memory was severely felt as a hindrance to his work, it does not appear, according to his own account, to have affected his spirits.

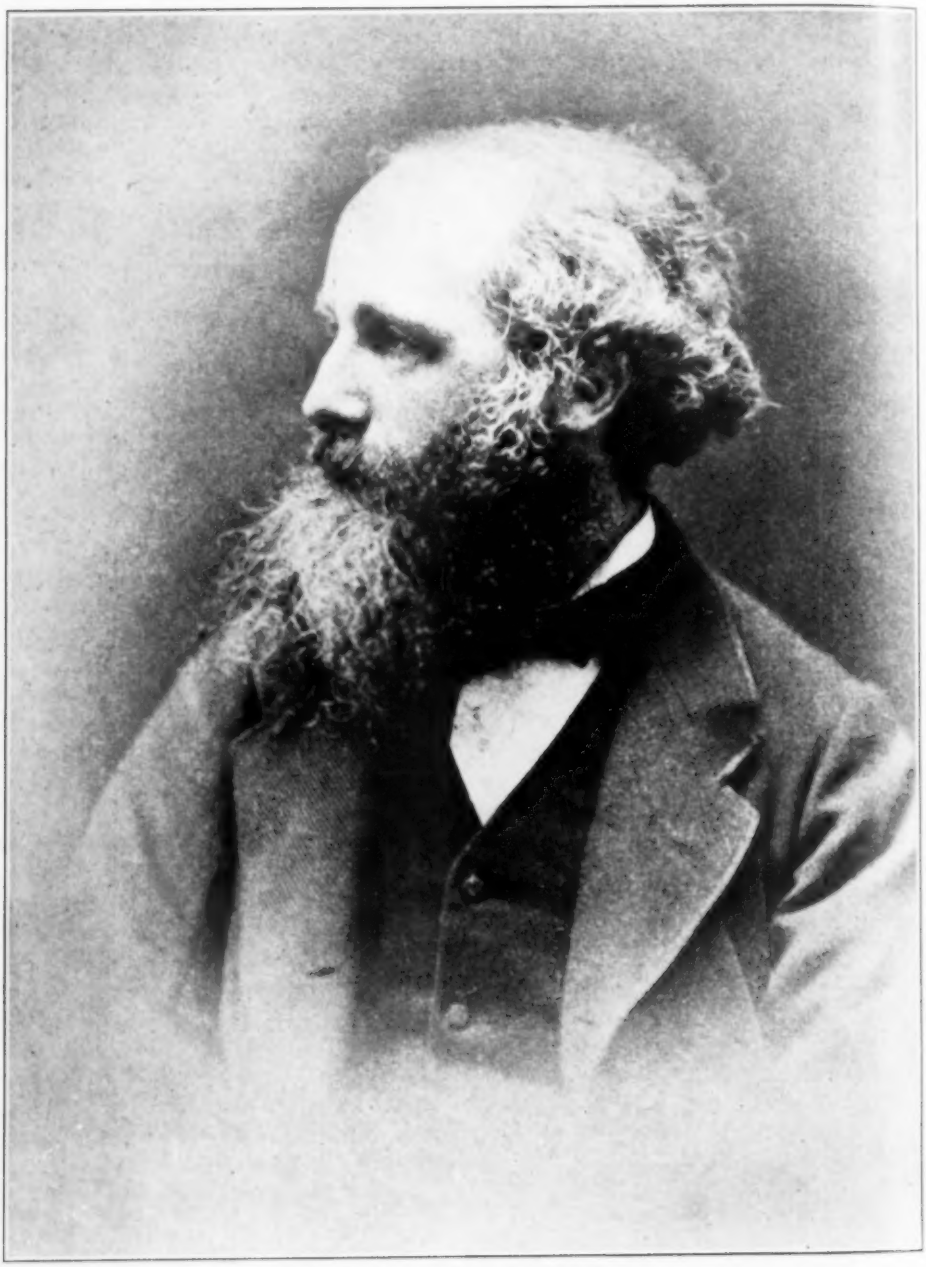
Religious Beliefs

Lastly, I come to one of the most interesting aspects of Faraday's life: his religion. It would not be right to pass it by, as we may shrewdly believe that Faraday would have done had he been charged with the task of giving an account of himself. His attitude is clearly characteristic, and our chances of understanding him would be less if we paid no regard to it. Faraday was a member of a small and isolated sect known as Sandemanians, after their founder. Their beliefs implied a very simple form of worship: they demanded spiritual reverence, a close adherence to the teaching of the Scriptures, mutual help in matters of religion, and general charity. With this little body Faraday associated himself at the appointed times, cutting himself adrift, to outward appearance, from all his science. He did not even inform his wife of the moment when he made his profession of faith and was formally received into fellowship. He took his part in the worship, though, it is said, with a hesitation and difficulty that were totally absent in the lecture theater. The injunctions to charity were certainly fulfilled: it is known that he gave large sums away, though he kept no account whatever of his gifts as he kept careful records of his scientific work.

If this complete separation of his religion from his science seems strange, we must remember that it would not seem so strange to any of us if we could put

ourselves back into his days: and I think it may be added that to some of us it would not seem strange even now, if we consider what Faraday may have meant by it. Remember that he himself was filled with a vision: he had actually been himself the first to see the workings of some of the great laws of the universe, and the unity of it all possessed him. Here were facts in natural accordance with the universal presence and power of the One God he had been taught to believe in. But his experiments could tell him nothing more of the qualities of that God. They fitted perfectly into their place, but they were trifles in comparison with the wider vision which he believed that his own spirit could ponder on and hope to see. This he sought in the quiet of his fellowship. We do not know, of course, to what extent he was satisfied. He was intensely reserved in religious matters: in answer to one correspondent he even deprecated religious discussion as generally unprofitable, but this was certainly a statement for a special occasion, and as a general expression of his attitude would go much too far. His attachment to a simple communion can cause us no surprise. He would, in the first place, be guided by his family tradition, and in the second place his own tastes were against any display. We ought not to go further in the attempt to see into Faraday's mind in religious matters: all that I may do legitimately is to give possible reasons for his very interesting attitude. For the rest Faraday was a very happy man, who was also a center of happiness, and we must judge by that.

It is Faraday's public life that belongs to us: it is one of the possessions of the nation, one of the great treasures. It is not only that his work has had such far-reaching consequences that all the world is affected by what he did, not only that he made plain the intricate connection between electricity and magnetism so that we are in daily dependence upon these forces of nature for the transfer of power and intelligence; it is not only that on his discoveries are now resting great British industries which are alive and are helping us through these difficult times. All these things are marvels so that we are proud of our famous countryman. But we all love the man himself for his simplicity of faith and purpose, for the breadth of his vision, and the humility of his thought, for his kindly generosity and for the light which he shed around him. He thought first of the quality of that which he gave, and only in the second place of that which he received in return. Could there be a nobler leading? Could there be any following more certain to bring us through times of depression and doubt to a triumphant ending?



JAMES CLERK MAXWELL

JAMES CLERK MAXWELL

(1831–1879)

By Dr. EDWIN H. HALL

EMERITUS PROFESSOR OF PHYSICS, HARVARD UNIVERSITY

THE scientific writings of Maxwell prove that he was one of the most potent intellects of his century. They, naturally, give no evidence, except an occasional gleam of humor,[1] of the fact that he was also one of the most genial and lovable of personalities.

Maxwell's paternal ancestors belonged to the "laird" class and to the intellectual aristocracy of Scotland. His mother's family, of Northumberland, were of like station and quality. There was legal ability and artistic talent on both sides of the house. The family name was originally Clerk,[2] but J. C. M.'s grandfather, George Clerk, added his wife's maiden name, Maxwell, as a condition for bringing a small landed estate into his family. J. C. M.'s father, John Clerk Maxwell, was a lawyer in Edinburgh, but upon his marriage he gave up the law and went to live on the Maxwell estate of Middlebie, later called Glenlair, in one of the southernmost counties of Scotland. His son was born in Edinburgh,[3] June 13, 1831, but the first ten years of the boy's life were spent at Glenlair, and his childhood speech had a very broad accent which, it seems, he never lost entirely. His mother died when he was eight years old. The father, who to the end of his life enjoyed an ideal intimacy with his son, had a great interest in all things mechanical and in all manufacturing processes, and this interest the son shared from his infancy. The boy was very active, both physically and mentally, and in all his activities there was a pronounced individuality. For gymnastics he rode a pony, became expert with a "leaping pole" (for crossing streams or other obstacles), learned to balance and paddle about in a floating wash-tub,[4] and practiced endlessly with a mechanical toy called "the devil on two sticks." This was a natural precursor of the famous "dynamical top" of his mature years. Another plaything was some form of whirling optical apparatus, for which he made drawings. This probably gave him the idea for his later "color-top" method of mixing color *impressions*, as distinguished from the mixing of *pigments*.

He was interested in and very sympathetic toward all manner of living creatures, and accordingly he, unlike his father in this, was no sportsman. He had a winning way with dogs, and in his later optical researches he could induce them to let him illuminate and examine their retinas, which he found very beautiful with patches of color. He read eagerly, intelligently and retentively, thus acquiring much knowledge without conscious effort; for example, a remarkable familiarity with the Bible. In spite of his abounding energy and high spirit he seems to have lived a blameless life throughout, with one exception. "One

[1] For example, on p. 3 of his "Electricity and Magnetism," in suggesting the wave-length of a particular kind of light as a standard of length, he remarks, "Such a standard would be independent of any changes in the dimensions of the earth, and should be adopted by those who expect their writings to be more permanent than that body." In a sense this suggestion of Maxwell's was adopted about twenty years later in the precise measurement, by Michelson in Paris, of the wave-length of the red line in the spectrum of cadmium.

[2] John Clerk, "Lord Eldin of the Court of Sessions," was of this family.

[3] Most of the material used in this paper is taken from the "Life" written by Maxwell's intimate friend Campbell.

[4] The accompanying picture illustrating this accomplishment is from a drawing by Jemima Wedderburn, a cousin, on his father's side, some years older than J. C. M.

MAXWELL CROSSING A POOL IN A WASH-TUB
A SCENE FROM HIS BOYHOOD DAYS DRAWN BY ONE OF HIS COUSINS.

evening at Glenlair, just as the maid-servant was coming in with the tea-tray, Jamsie blew out the light in the narrow passage, and lay down across the doorway."

Young Maxwell's formal education began inauspiciously at Glenlair under a private tutor whose unwise and even brutal method of discipline produced in the boy, according to his biographer, "a certain hesitation of manner and obliquity of reply which Maxwell was long in getting over, if, indeed, he ever quite got over them." I can not help suspecting, however, that this manner was due in some measure to a certain natural love of mystification, playful and rather engaging for the most part, in the boy he was and in the man he became. However that may be, when at the age of ten Maxwell entered Edinburgh Academy as a pupil, his somewhat odd behavior, combined with his rustic dress and speech, attracted the unfavorable attention of his fellow pupils, who proceeded to haze him in approved school-boy fashion and gave him a nickname, "Daftie," which clung to him for a year or two at least. They even, at first, thought him rather dull. The boy, however, had too much spirit and self-respect to be depressed by this treatment, and before the six years of his academy life had passed his true quality was recognized by his associates.

He wrote frequently to his father during these years at Edinburgh, showing his affection not so much by protestations as by the frolicsome humor of his letters. One of these, written when he was not yet twelve years of age, seems worthy of especial comment. It is elaborately decorated on its margins with pen work and it contains a number of drawings. The first part of the text is printed, the last part is in script so written as "to be read backwards through the paper." The letter begins with mention of a lecture which told how the American Indians kill buffalo by shooting them from horseback with a bow, and one of the drawings gives the boy's conception of this operation. This picture seems to me so remarkable that I have reproduced it here. The bow, of course, is absurdly small, meant to be so, and the backbone of the horse has apparently cut its way to the rider's waist-line. But the rider's legs grip the horse's body easily and securely, and every joint of the horse's legs is shown flexed in natural action. When it is remembered that this drawing was made by a boy of eleven years, a whole generation before instantaneous photography began to be used in the study of animal locomotion, the evidence of *action*, the sense of mechanical *func-*

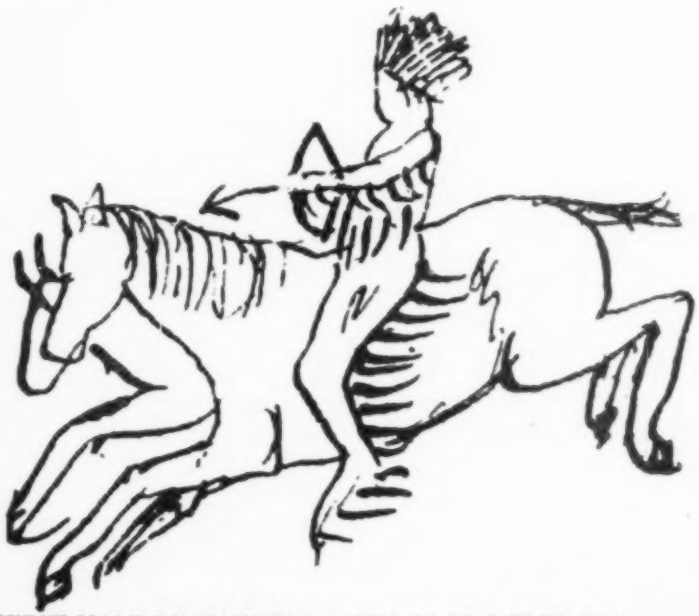
tion, which this figure of the horse shows is astonishing. Let any one who is inclined to question this statement study the next set of old English hunting-scenes that may come to his attention and see whether he can find the figure of a running horse represented in any other attitude than that of a child's rocking-horse, forelegs extended forward, hind legs extended backward, the farther the better.

As a boy and as a man Maxwell was fond of writing verse, usually humorous verse, and in the Academy he excelled in English. He stood well in Latin also, but concerning the composition of Latin verse he writes to his father, "When I lithp in numberth it ith but a lithp, for the numberth do not come." In mathematics at the Academy he stood in a class by himself. Before he was fifteen years old he had written a paper describing a method of drawing ovals of various kinds, and this paper was by Professor Forbes and Professor Kelland, of Edinburgh University, so well thought of that it was presented at a meeting of the Royal Society of Edinburgh with favorable comment.[5]

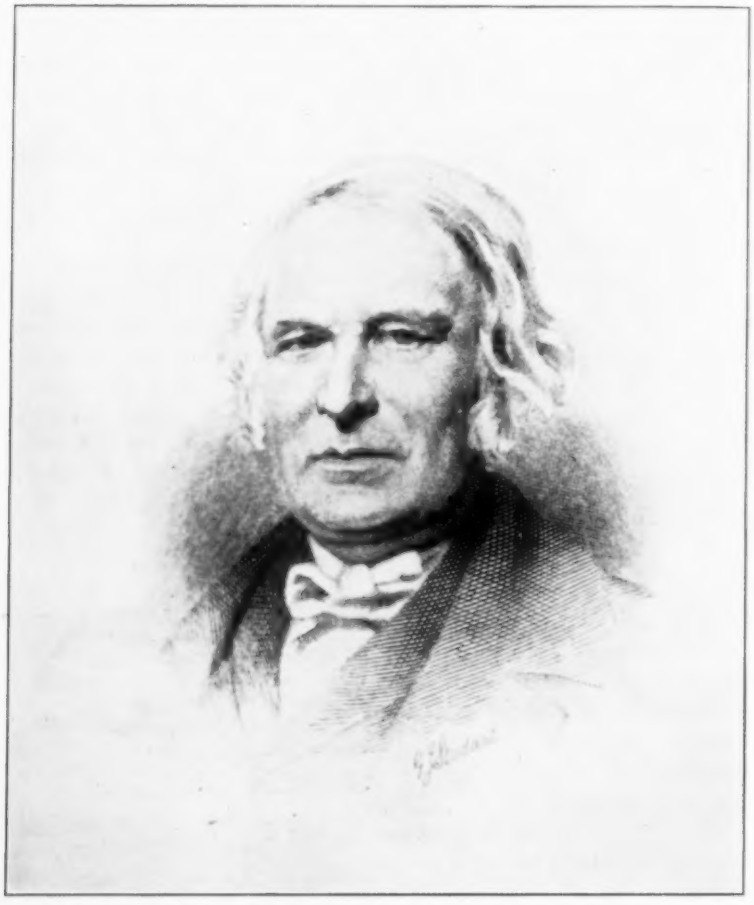
Maxwell entered the University of Edinburgh in 1847, when he was sixteen years old, and he remained there three years. He found competent men in the chairs of physics, chemistry and mathematics, and he studied with all of them, maintaining his interest in matters of science but with no great pressure of attention. In fact, it appears from Campbell's "Life" that Sir William Hamilton,[6] professor of mental philosophy, made a more profound impression upon Maxwell's mind than any other of his Edinburgh teachers. He attended also lectures given by the professor of moral philosophy, John Wilson, better known as Christopher North, the name

[5] The paper was entirely original with Maxwell, though it was finally discovered that Descartes had drawn ovals in the same way.

[6] Not to be mistaken for his contemporary Sir William Rowan Hamilton, the famous Irish mathematician. In drawing up a plan of future study, at the end of his course at Edinburgh, Maxwell included reading of Kant's *Kritik of Pure Reason* in German, "*with a determination to make it agree with Sir W. Hamilton.*"



A SKETCH MADE BY MAXWELL WHEN HE WAS ELEVEN YEARS OLD



JOHN CLERK MAXWELL
THE FATHER OF JAMES CLERK MAXWELL.

under which his celebrated contributions to *Blackwood's Magazine* were made. Maxwell's interest in the subject of these lectures was deep and lasting, but he had no great respect for the teaching of Wilson.[7]

The liveliness of his mind and the variety of his interests at this period may well be illustrated by extracts from certain of his letters. Thus in 1848, after telling of several mathematical or scientific "props" (propositions) of which he was thinking, he says, "I don't understand how you mug [work] straight on. I suit my muggery to my temper that day. When I am deep I read Xenophon's defence of Σωκ; when not I read Σωκ's witty dialogues. If I do not do this, I always find myself *reading Greek*, that is, reading the words with all their contractions, as a Jew reads Hebrew. I get on very rapidly; but I know nothing about the meaning, and do not even know but that I am really translating." A letter of 1849 begins thus: "Here is the way to dissolve any given historical event in a mythical solution, and then precipitate the seminal

[7] In a letter written in 1850 he says "Wilson, after having fully explained his own opinions, has proceeded to those of other great men: Plato, Aristotle, Stoics, Epicureans." "He quarrels with Aristotle's doctrine of the Golden Mean—'a virtue is the mean between two vices'—not properly understanding the saying."

ideas in their primitive form. It is from Theodore Parker, an American, and treats of the declaration of American independence. 'The story of the Declaration of Independence is liable to many objections if we examine it *á la mode Strauss*.[8] The Congress was held at a mythical town, whose very name is suspicious—Philadelphia, brotherly love,' '' etc.

While in the University of Edinburgh Maxwell wrote two scientific papers which Tait,[9] a competent critic, many years later declared to be ''valuable,'' and which were published in the *Transactions* of the Royal Society of Edinburgh. It was probably in regard to one of these that Professor Forbes wrote to Maxwell as follows, in May, 1850: ''Professor Kelland, to whom your paper was referred by the Council R. S., reports favourably upon it, but complains of the great obscurity of several parts, owing to the *abrupt transitions* and want of distinction between what is *assumed* and what is *proved* in various passages,'' etc. This criticism of Maxwell's style in the presentation of his scientific ideas and theories is a valid one. He never acquired pedagogic skill.[10]

It appears that during most of his student life at Edinburgh Maxwell had some thought of following his family tradition and taking to the law. But when, in October, 1850, he entered Cambridge University, he had definitely committed himself to physical science. He at first was in Peterhouse but soon went to Trinity College. He there became a pupil of Hopkins, a famous tutor of the time, and set himself to the long grind of preparation for the Mathematical Tripos. But in all the routine of this training his individuality continually asserted itself. He had, for example, a predilection for graphical, as compared with algebraic, methods of discussion. ''Whenever the subject admitted of it he had recourse to diagrams, though the rest might solve the question more easily by a train of analysis.'' His realization of spatial and physical relations was exceptionally vivid, and in all his scientific discussions, though he was often obliged to put his trust in mathematical formulae incapable of immediate physical interpretation, his constant endeavor was to visualize the problem with which he was dealing. Hopkins said of him, ''It is not possible for that man to think incorrectly on physical subjects.''

In his diversions also he continued to be unusual. A contemporary of his at Cambridge says: ''From 2 to 2:30 A. M. he took his exercise by running along the upper corridor, down the stairs, along the lower corridor, then up the stairs, and so on'' till the other inhabitants of the building rose in wrath and threw things at him. Tait, who knew Maxwell at Cambridge, as he had known him years before in the Edinburgh Academy, relates that ''He used to go up on the pollard at the bathing-shed, throw himself *flat on his face* in the water, dive and cross, then ascend the pollard on the other side, project himself *flat on his back* in the water. He said it stimulated the circulation!''

A description of his personal appearance as a young man should be given here. ''A slight contraction of the chest, and a stature which, although above the average, was not tall enough to carry off the weight of his brow,[11] made him less

[8] Strauss wrote the ''Life of Jesus'' in a spirit of historical skepticism. Theodore Parker was a famous Unitarian clergyman of Boston.

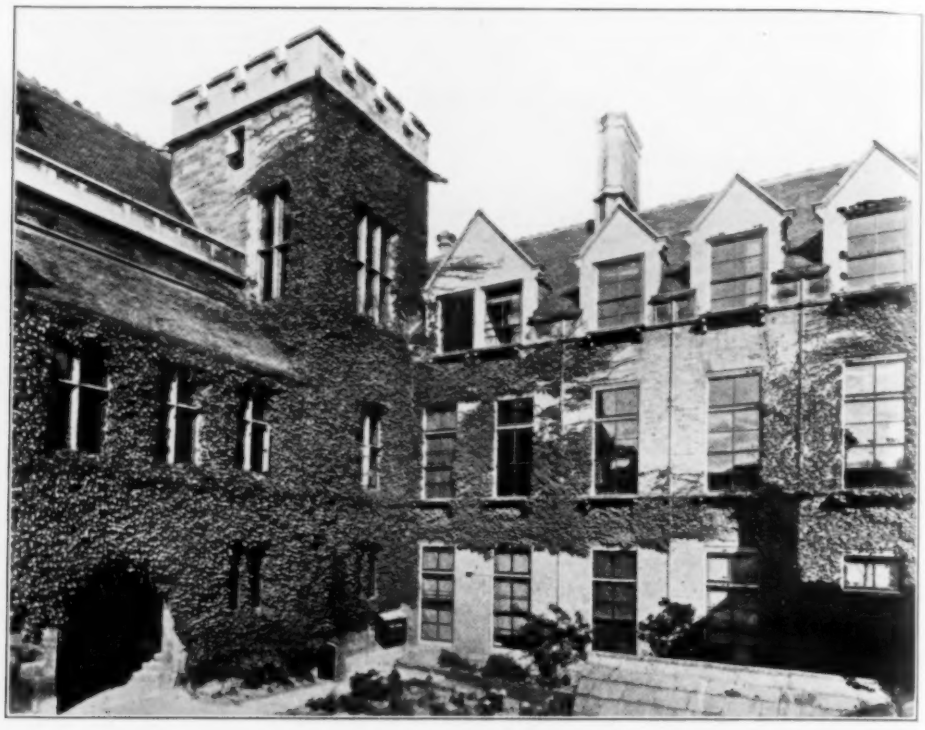
[9] Tait and Maxwell were rival candidates at one time for the professorship of natural philosophy at Edinburgh. Tait won, but the two men remained intimate friends. I once heard Tait recite some humorous lines written by Maxwell satirizing Tyndall's style as a popular science lecturer.

[10] Professor E. L. Nichols, of Cornell, who had studied under Gustav Wiedemann in Germany, told me that Wiedemann, on hearing that some student professed to have read Maxwell's "Electricity and Magnetism" in two months, exclaimed, ''Read Maxwell in two months! Maxwell himself couldn't read it in two years.''

[11] Rowland before assuming the duties of his professorship at Johns Hopkins had by his experimental researches attracted the highly favor-

THE BOY MAXWELL WITH HIS MOTHER

MAXWELL IN HIS YOUTH



THE CAVENDISH LABORATORY

THE PHOTOGRAPH SHOWS THE ORIGINAL WING BUILT BY MAXWELL AND OPENED IN 1874.

handsome standing than sitting." But his presence had a charm which made him the center of any circle of his friends. His eyes were dark brown, "his hair and incipient beard were raven black, with a crisp strength in each particular hair." His dress was quiet but showed a nice sense of color, for his eye was both naturally sensitive and highly trained by experimental study.

Like other college undergraduates Maxwell thought much of religious matters, but with a combination of boldness and reverence somewhat rare. "Nothing is to be *holy ground* consecrated to Stationary Faith, whether positive or negative. All fallow land is to be ploughed up, and a regular system of rotation followed. All creatures as agents or as patients are to be pressed into the service, which is never to be willingly suspended till nothing more remains to be done; *i.e.*, till A. D. $+\infty$. The part of the rule which respects self-improvement by means of others is: Never hide anything, be it weed or no, nor seem to wish it hidden." He declared that "Christianity—that is, the religion of the Bible—is the only scheme or form of belief" which has nothing to hide. He expressly disclaims, however, the proposition that no *Christian* has any *tabooed* spots in his faith.

A bit of literary criticism, emitted when he was twenty years old, is this: "Do you ever read books written by women about women? I mean fictitious tales, illustrating Moral Anatomy, by disclosing all thought, motives, and secret sins, as if the authoress were a perjured confessor." But I must resist

able attention of Maxwell and had visited the latter in England. I once heard him say, speaking of Maxwell, "I tried on his hat. It was too big for me."

the temptation to quote further from Maxwell's miscellaneous reflections of this period.

From the Mathematical Tripos of 1854 Maxwell emerged as Second Wrangler, E. J. Routh[12] being the First, or "Senior," wrangler. In the Smith Prize competition, however, a higher test, Maxwell and Routh were "bracketed" together. It has happened more than once, and this is one of the instances, that the Second Wrangler has proved to be in later life a far greater and more important figure than his Senior.

After taking his degree in 1854 Maxwell stayed on at Cambridge for two years, as a Fellow of Trinity College. He did not in this position shirk the routine of teaching and conducting examinations,[13] but he was now able to renew his activities in experimental and theoretical research. He returned to the study of color, a study in part psychological or physiological, and he set himself with great zest to the task of reducing Faraday's conception of "lines of force," electrical or magnetic, to definite mathematical form; for Faraday, though an inspired experimenter and theorist, was no mathematician. The spirit that animated Maxwell in all his labors may be expressed in words of his own, written about this time: "Happy is the man who

[12] Routh wrote a number of mathematical works that were well known, but he was perhaps more famous as a great mathematical "coach" than as an author.

[13] Moreover, he undertook work of a benevolent character quite outside the formal duties of his position, as the following extract from a letter of March, 1856, will show: "I was at the Working College to-day, working at decimal fractions. We are getting up a preparatory school for biggish boys to get up their preliminaries. We are also agitating in favour of early closing of shops."

GLENLAIR HOUSE, CORSOCK, DALBEATTIE

MAXWELL'S CHILDHOOD AND MUCH OF HIS LATER LIFE WERE SPENT AT GLENLAIR. IT WAS HERE THAT THE GREATER PART OF HIS "ELECTRICITY AND MAGNETISM" WAS WRITTEN. THE PHOTOGRAPH SHOWS THE APPEARANCE OF THE HOUSE AFTER IT WAS ENLARGED BY MAXWELL.

can recognize in the world of to-day a connected portion of the work of life, and an embodiment of the work of Eternity."

His father died in 1856 at Glenlair, the son being with him and ministering to him at the last. Maxwell, who often expressed his moods, whether grave or gay, in verse, wrote soon after this a poem containing these lines:

For it is not all a fancy that our lives and theirs are one,
And we know that all we see is but an endless work begun.
Part is left in nature's keeping, part has entered into rest;
Part remains to grow and ripen hidden in some living breast.

An engraving from a painted portrait of the father is here reproduced. It shows a countenance well befitting the father of an eminent son.

For three years, from 1856 to 1859, Maxwell held the "Chair of Natural Philosophy" at Marischal College, Aberdeen. The conditions of his life there were not altogether congenial. He was not a good lecturer for commonplace minds, and Aberdeen, where general public sentiment was in favor of a utilitarian education, did not supply the best of material for his classes. "The spirit of indirectness and paradox . . . would often take possession of him against his will and . . . would land him in 'chaotic statements,' breaking off with some quirk of ironical humor." He declares in one of his letters, "no jokes of any kind are understood here. I have not made one for two months, and if I feel one coming I shall bite my tongue."

But he set himself energetically and not unsuccessfully to his task. In 1857 he writes, "I am at full college work again. A small class with a bad name for stupidity. . . . So I have got into regular ways, and have every man *viva voce'd* once a week, and the whole class examined in writing on Tuesdays, and roundly and sharply abused on Wednesday morning," etc. "Public Opinion here says that what our colleges want is inferior professors, and more of them for the money. Such men, says P. O., would devote their attention more to what would pay."

He volunteered to give lectures for workingmen, however. "Tuesday week I gave a lecture to operatives, etc., on the Eye. I have just been getting cods' and bullocks' eyes, to refresh my memory and practise dissection." Some of the students whom he "sharply abused" entered voluntary classes to continue under his teaching.

But in 1860 the two colleges of Aberdeen, Marischal and King's, were united, and Maxwell's chair was abolished in this fusion. He was then for a short time without a teaching position.

He had, while at Aberdeen, carried on and completed his research on the Rings of Saturn, showing that they must consist of separate small satellites of the planet. Another achievement of his life there was his marriage, in 1858, to Katherine Mary Dewar, daughter of Principal Dewar of Marischal College.

"From this point onward," says his biographer, "the interest of Maxwell's life (save things 'wherewith the stranger intermeddles not') is chiefly concentrated in his scientific career." In the summer of 1860 he was appointed to the professorship of natural philosophy in King's College, London, and he remained in this position, which was a laborious one, till 1865. He thereafter lived in retirement, at Glenlair, till 1871, when he was appointed, without opposition, to the newly established chair of experimental physics in the University of Cambridge, Sir William Thomson having declined to be considered for this position. One of the first to urge Maxwell's acceptance was the Hon. J. W. Strutt (Lord Rayleigh), who was Maxwell's successor in the same chair. Maxwell entered this new undertaking with some misgivings, saying that he had no experience in directing experimental work and intimating

that experimental investigation would involve an amount of dull labor that might not be attractive to men of Cambridge education. The world is well aware now how brilliantly Cambridge men have proved their willingness and their ability to go through the drudgery of research to the highest achievements of discovery.

Maxwell's first work in his new position was to design the Cavendish Laboratory and superintend its construction. This building was completed and opened for operation in the spring of 1874, only two years before Rowland began the work of research in his very unpretentious laboratory quarters at Johns Hopkins.

Maxwell's greatest work, his "Electricity and Magnetism," was published in 1873. This book starts with Faraday's conception that electrical and magnetic attractions and repulsions are not direct *actions at a distance* by the electrical or magnetic bodies concerned, but are due to a state of the medium between these bodies. This conception as developed mathematically by Maxwell, with his passion for attaching a concrete physical meaning to all his mathematical expressions, led finally to his electromagnetic theory of light. For several decades light in its objective sense had been explained as a progression of waves, alternations of physical state, in the medium through which it travels. Maxwell reached the conclusion that these progressive alternations are alternations of electrical and of magnetic state in the medium, and showed that, if this theory is true, certain definite numerical relations should hold between quantities measured in the phenomena of electricity and magnetism and quantities measured in the phenomena of light. This may be illustrated as follows: There are two ways of measuring quantities of electricity; one, called the *electrostatic*, is based on the attraction or repulsion of electrically *charged* bodies; the other, called the *electromagnetic*, is based on the *magnetic* action of an electric *current*. Maxwell inferred from his theory that, if the centimeter, the gram and the second are used as the fundamental units of physical measurement, the ratio of the electromagnetic unit to the electrostatic unit of electricity must be equal to the velocity of light, measured in centimeters per second, in a vacuum.

So a little more than half a century ago the leading physicists of the world set themselves to measure, with the greatest accuracy attainable, the "ratio of the units" on the one hand, and the velocity of light on the other hand. America made its contribution to these investigations. Rowland at Baltimore made one of the best determinations of the units ratio. Michelson at Annapolis improved upon all previous measurements of the velocity of light. The more accurate experimental results have become, the more closely has the relation predicted by Maxwell's theory been verified.

It followed, of course, from Maxwell's conception that from any source of rapid and regular alternations of electric discharge equally frequent and regular alternations of electric state travel outward through the surrounding space with the velocity of light. Heinrich Hertz some years after Maxwell's death gave experimental proof of the existence of these traveling alternations, or electromagnetic "waves," detecting them by means of an electric receiving oscillator having the same natural period of vibration as the source. Thus the fundamental principle of the now almost too familiar "radio" action was discovered.

Maxwell died on November 5, 1879, being then 48 years of age. During his last days he said to a friend: "Old chap, I have read up many queer religions: there is nothing like the old thing after all;" and—"I have looked into most philosophical systems, and I have seen that none will work without a God."

A RETROSPECT OF WIRELESS COMMUNICATION[1]

By Sir OLIVER LODGE

As one gets older people seem to think that one's duty is to be a historian of the times during which one has lived. Unfortunately I have not been trained as a historian, and am therefore incompetent to do more than just trade upon my reminiscences, which are liable to be rather one-sided and not to satisfy the conditions for serious and reliable history without prejudice or favoritism. It has been suggested that I speak on the history of wireless telegraphy, under the title "A Retrospect of Wireless Communication."

Looking back, then, over my lifetime, the first item to attract my attention was a paper on "Transient Currents" written by Lord Kelvin (as Sir William Thomson) in 1853, wherein he gave the theory of electric oscillations in a masterly manner, considering that the idea of self-induction was not then born. He knew, however, that an electric charge could be stored in a condenser, after the same fashion as energy is stored in a bent or coiled spring, so that the condenser received and stored up electric energy, which it would subsequently give out when released. That was the first step. He knew, moreover, that the discharge would constitute an electric current, and that every electric current was surrounded by a magnetic field, which would confer upon it something akin to inertia or momentum; so that, like a loaded spring, it would not only recoil when released, but would overshoot the zero mark and reverse of itself, swinging like a loaded pendulum first on one side the zero, then on the other; so that the discharge was not a flow in one direction only, but an oscillating or alternating flow, first in the positive, then in the negative direction. The magnetic field would thus prolong the discharge until the energy was finally wiped out; and the spark, if examined in a rotating mirror (as Feddersen examined it twenty years later) would be seen to be not a single luminosity, which would be drawn out into a uniform band, but would be a succession of luminosities or a beaded band, each band corresponding to a half swing. Kelvin did not attempt this experimental verification, but he went on with the theory.

The elastic recoil or strength of the spring varies inversely with the capacity of the condenser. The smaller the condenser, the stiffer the spring; so that with a large condenser the oscillations would be fairly slow; not really slow, but something comparable to a thousand or a hundred a second, something which could be made to give a musical note, if the capacity were very large. I exhibited this musical note at the Royal Institution many years afterwards in what I called a "whistling spark." The noise of such a spark, instead of being a crack, was a whistle, whose pitch could be brought down to reach the tones of the voice, and indeed lower still. The rate of swing depends not only on the capacity of the condenser; it depends also on the load or inertia of the discharging circuit. It depends on what we now call self-induction, but which then Kelvin spoke of as "the electro-dynamic capacity of the discharger." There was the electrostatic capacity of the charged condenser, and the electrodynamic capacity of its discharging circuit. The two cooperated so as to produce the

[1] An Evening Discourse delivered at the Centenary Meeting of the British Association for the Advancement of Science, London, September, 1931.

swing, and the rate of swing depended on both equally, and could be calculated exactly. This theory Sir Richard Glazebrook and I subsequently verified, many years afterwards, in the Cavendish Laboratory, Cambridge, in the nineties of the last century, the result being published in the Stokes Memorial Volume.

The discharger not only had magnetic induction, it also had resistance, and Kelvin's theory showed that if the resistance was above a certain amount, the oscillations would be quenched prematurely. There was a critical resistance at which they would be wiped out, so that the recoil would be dead beat, just returning to zero and staying there. That was the quickest possible method of discharge. But there would then be no oscillations. if the resistance were still greater than that, then the discharge would take longer to reach zero; it would degenerate into a leak, or at first into a sort of intermittent current, returning towards zero spasmodically in jerks all in the same direction.

Now a flash of lightning is the discharge of a condenser, that is, the discharge of a store of electricity in the cloud; and Dr. Simpson, the eminent meteorologist, has shown that the resistance to a flash of lightning usually exceeds the critical value which would make the discharge dead beat, and still more exceeds the value which would permit it to be oscillatory, and in fact makes it intermittent; so that the lightning, if photographed, is seen to be a series of spits, succeeding one another very rapidly, and giving a jerky current all in one direction. Lord Kelvin's theory of 1853 provided not only for the oscillatory discharge and its dead beat condition, but also for the leak likewise. If the resistance was enormous then the charge of the condenser would simply leak away, the law of discharge being then exactly like that of a hot body cooling. For heat has no inertia, and therefore has no tendency to make oscillations. The hotter the body the more rapid the leak, that is to say, the cooling process: and the return to zero is asymptotic, that is to say, the potential falls down an exponential or logarithmic curve, getting slower and slower as it comes nearer zero, and gradually approaching it, taking theoretically an infinite time actually to attain it. That theory of Lord Kelvin's about electric oscillations or what he called transient currents dominated for me the nineteenth century, and was illustrated by innumerable experiments, at different times in the century. In the year 1889 I lectured on the Leyden jar at the Royal Institution, and showed many of these effects.

But we did not know then that there was another reason for reducing the time during which the charge continued to oscillate. It was killed not only by the resistance of the circuit, but by a certain proportion of energy radiated away into space. We did not know that there was any such radiation, nor did Lord Kelvin. We knew, or might have thought, that such radiation was possible, by the analogy of a tuning-fork. A struck or excited tuning-fork gives sound vibrations which die out at a certain rate. They die out partly because of the resistance of the steel of the fork, and partly, indeed chiefly, if the fork is mounted on a sound-board, by reason of the radiation which is thrown out into the air. A genius might have surmised that, as the tuning-fork vibrates in air, so the discharge of a Leyden jar or other condenser, being a vibration in the ether, might possibly carve the ether into waves and emit energy in that way. That is what happens, but no one suspected it for a long time; they did not know that the conditions for ether waves would be satisfied by an electric discharge. We had no sense for such waves, and could not tell that they were being emitted, even when we made the experiment. We were in the condition of a deaf person striking a tuning-fork or a bell. If

you could not hear the sound emitted by the fork you would not know that there was any; and you would certainly not experiment on the waves, measure their wave-length, and utilize them for purposes of communication.

The first to show that an electric discharge would generate such waves, that is to say that an alternating or oscillating current would lose a certain fraction of energy to the ether at every swing, was George Francis FitzGerald, who in the year 1880 examined the question mathematically, communicating it to Section A of the British Association; and in 1883 followed it up with a further communication, in which he calculated the actual amount of energy lost in a second by a given condenser and self-induction. This was a great feat, and I will write FitzGerald's result on the board, for it is used to this day. It showed that a short wave oscillator radiated much more vigorously than one that vibrated slower; that the radiation power, in fact, depended on the fourth power of the frequency, other things being equal.

The radiating power of a current i oscillating in a time T in a circle of area πa^2 is

$$\frac{8\mu\pi^4}{3T^4c^3}\cdot(\pi a^2 i_0)^2$$

which simplifies to this in terms of wave-length

$$8\times 10^{13}\frac{(\pi a^2 i)^2}{\lambda^4}.$$

His theory shows why an ordinary alternating dynamo does not radiate appreciably; it does radiate, like every alternating current, but if its frequency is comparable to 100 a second the amount of energy lost is next to nothing. To get at anything like efficient radiation you must have an alternating current of a million a second or more; and if you could only work up the oscillations till they were five hundred-million-million a second (which sounds preposterous) then you would have the means of detecting them. They would be sufficiently rapid than to excite our sense-organ, the eye, and give us the sensation of a strong yellow light; for what we call light is just an etheral vibration excited by an electric oscillation of this extravagant frequency.

Still we didn't know how to produce these oscillations, and still less how to detect them. FitzGerald virtually said that the oscillations were there whenever a Leyden jar discharged. On what ground was he able to make that assertion? How did he know that an electrical oscillation would generate ether waves just as a tuning-fork generates sound waves? He only knew that on the strength of the work of a great genius, James Clerk Maxwell, who in 1865 communicated papers to the Royal Society and to the British Association a year or two later, giving the result of his mathematical theory of Faraday's views on electromagnetic phenomena. Maxwell's equations expressing electric and magnetic relations were, and still are, of the utmost importance. They are not expressed in the simplest possible form, but they are remarkably complete. Simplification came later. But as a foundation for all the work that followed during the century, Maxwell's equations are the basis, and shine with undiminished brightness down to the present day.

This leads me to make a digression on the work and methods of mathematical physicists. Their plan in studying any phenomenon is to bethink themselves of what is the fundamental fact or process underlying it. They express that process in what to them is the simple form of an equation, and having written down equations appropriate to each aspect of the phenomenon, they proceed to combine these equations according to certain rules, the rules of pure mathematics, and deduce the consequences. It is not a process that comes naturally to ordinary people; indeed, they find a difficulty in following it. When they do follow it,

they are apt to be lost in admiration, first for the insight which enabled them to express the fundamental laws in that tractable form, and next for the skill with which the forms have been manipulated, so that results could be interpreted which might subsequently be put to the test of experiment and thus verified. Verification is always necessary because, though the theory may be accurate as far as it goes, it never goes all the way, and it may fail in not going far enough. A complete theory of any phenomenon would have to take all the universe into account, but no one aims at such a complete theory: they take the most essential features of what is happening and ignore the rest. It takes some genius to perceive what the most essential features are, and to judge whether the other things may be ignored or not. When the theory fails to be verified in practice it means either that some error has been made in the calculation, or, more probably, that something has been ignored which ought not to have been ignored. Thus, for instance, to take a trivial example:

Professor Tait, the great mathematician of Edinburgh, calculated the trajectory of a golf ball, taking into account a good number of the causes governing it—the impact of the head of the club, the inertia and elasticity of the ball, the resistance of the air, the force of gravity, and so on. His first theory gave him a maximum range which no one, however skilled, could hope to exceed. Then, as is well known, his son, Lieutenant Tait, a skilled golfer, exceeded it. What did Tait do? He didn't abandon the theory; he perceived that something more must be taken into account. What he had ignored as unimportant was the spin on the ball. A ball when struck except in a line exactly through its center, will not only move forward but will be set spinning. Every one knows the effect of spin on a billiard ball. A skilled player purposely puts it on by the way he strikes the ball; it will then rebound from the cushion or from another ball in a way different from what it would if it were not spinning. A spinning ball might move in a curved line. But then a billiard ball is rolling on a table, a golf ball is not. Still, it may be rolling on the air through which it is moving. Tait perceived that the spin must not be ignored, but must be fully taken into account. He remodelled his theory, writing down some more equations to take the spin energy into consideration. He thus made a more complete theory, which led to curious results, most of which have now been verified by experiment. The practice and the theory agreed to a sufficient approximation, and the theory is then said to be complete. I am only taking this as a typical instance of the way in which mathematics is applied to physics, to secure in this instance a trivial result. Of course, a mathematician might have taken the whole into account at first, and then the theory would have been complete from the beginning and there would have been nothing to correct afterwards.

That was the kind of way in which Newton proceeded. When he gave his theory of astronomy based upon gravitation he at first took the heavenly bodies, first as particles then as spheres, and thus arrived at a first approximation to the theory of their motions. But he knew that the earth itself could not be a sphere, because it was spinning on its axis; it must be an oblate spheroid. That had never been observed, but Newton predicted that it was so, and proceeded to trace the remote consequences of the shape of the earth. He found that it accounted for the precession of the Equinoxes, which had been known as an empirical fact to the ancients. Copernicus had said that precession must represent a conical motion of the earth's axis; but no one knew any cause for such a conical motion. Newton with his extraordinary genius perceived that a conical motion, very slow and taking thousands of years for its revolution, would be the

exact result following from the pull of gravitation on an oblate spheroid. A spheroid would not act as if all its mass were concentrated at its center; it would be more complicated than that. He was not deterred by the complications, but worked them out and completed his theory.

Another thing that had been ignored in the first view of astronomy was the size and plasticity of the bodies; they were treated as particles or rigid bodies, and this gave the first approximation. But obviously the earth is not a particle but a body of considerable size, so that some parts of it are appreciably nearer the sun or the moon than are the parts at the Antipodes. Newton took the size into account, and thus was able to show that anything yielding or mobile on the surface of the earth, like the ocean, would have a motion distinct from the rest of the earth to a slight extent, and would go through an oscillation periodically. This oscillation of the water on the earth he perceived would account for a phenomenon that had been known from antiquity, but had never been explained, namely, the tides. He completed his theory by working out the tides in all their main detail, leaving it to others to show how great an effect tidal phenomena had had on the evolution of the universe.

This has been recently extended and applied by Sir James Jeans to the production of a solar system. He has shown mathematically that if a visiting sun entered our neighborhood, coming within a reasonable distance of our sun, it would excite tides upon the sun, which might increase to such an extent as to throw out an explosion or protuberance. The history of this he followed up, and showed that it would presently aggregate into round bodies revolving round the earth, the bigger ones in the middle of the protuberance, the smaller ones at either end, and thus provide the sun with a system of planets, on one of which we happen to live. Well, that is a further development of tidal theory, taking into account all the possibilities, or at any rate such of them as a genius is able to consider relative, and giving an idea which at present seems likely to hold against adverse criticism about the origin or creation of the earth and other planets. This again is a digression, and I do not see how the theory is to be verified by experiment. All this development could not be done by one man; the genius who made it possible is Isaac Newton. The further developments of his theory were left to posterity.

So it was also with Clerk Maxwell. He wrote down some equations which expressed what Faraday had long brooded over as the electric field, regarding it as distinct from matter and existing in the ether of space around the charged body. He also wrote down another set of equations expressing the magnetic field surrounding a current. And then he began to combine these, so as to see what an electromagnetic field would be like, that is to say, a field which combined an electric displacement with a magnetic whirl. Do not suppose that this was an easy thing to do, but Maxwell did it, and found (possibly to his surprise, possibly to a satisfaction of his instinct in that direction), that the equation he now got, a differential equation of the second order, was one that was familiar to him and to other mathematicians, namely, the equation to a wave; that is, a disturbance periodic in space and time, which advanced through space at a certain rate. This rate was expressed by an electric and a magnetic constant of the ether, which were immeasurable; no one knows to this day how to measure them. But the rate of propagation of the electromagnetic wave did not require the separate constants to be measured, nor need we know what each was; only their product entered into the expression. Experiments made abroad, in Germany, had indicated a way of determining this

product; Maxwell bethought himself of another method, and proceeded to put it into practice in the laboratory of King's College, London, where he was then a professor. He performed the experiment, worked out the result, and obtained a speed for the transmission of electromagnetic waves very close to the velocity of light. It looked as if ether waves were just what we had been using all along for optical experiments and for arousing our sense of vision. We had been discussing whether ether waves were possible; they were familiar, only we didn't know they were electromagnetic.

All manner of theories of light had been tried in the early part of the nineteenth century—very ingenious theories, depicting the ether as a kind of elastic solid or jelly, in which the vibrations travelled at an immense pace. But none of these theories had been satisfactory. They covered the ground to a great extent, but they failed sooner or later. There were things we could not account for by any elastic solid theory. But Maxwell's theory that light was not mechanical but was an electromagnetic phenomenon, that its laws were ascertainable by electric and magnetic experiments, was a tremendous eye-opener. His book was published in 1873. The president of Section A of the British Association called attention to it, and we young people were all agog to understand this theory better, and if possible to verify it by actually producing ether waves electromagnetically. That was what set FitzGerald to work, and I have given you an indication of his results.

I also set to work experimentally, and tried to produce the waves by the discharge of Leyden jars. No doubt I did produce them—that was easy enough; the thing was to detect them. The eye is useless for waves measured in meters; it can only deal with the excessively rapid vibrations that constitute light. We needed what Lord Kelvin called "an electric eye." We worked mainly with closed condensers—that is to say, things of which the opposite plates were near together—and tried to see if there was any sign of waves running along wires which were attached to such discharging condensers. In 1887 or '88 I got the evidence in the form of nodes and loops characteristic of ether waves, reflected back on themselves at the terminal of the wire. But Heinrich Hertz in Germany, though not himself seeking to verify Maxwell's theory, which had not attracted much attention on the Continent, but making experiments on the way in which electric force streamed out from a discharging conductor, arrived at a sensational result. He did not work with closed circuits. He took two plates, like the two coats of a Leyden jar, separated from one another as far as possible, and joined by a wire: in fact, he made what we now call a Hertz vibrator. It can hardly be called a condenser, but still it has capacity and self-induction, that is, the two ingredients necessary for an oscillation, and when the two surfaces were charged oppositely and sparked into one another, oscillations were set up, and waves were generated, as FitzGerald had perceived they would be. They were generated in space, however, because the electric field was spread out in space as well as the magnetic. They had such energy, these waves, that when they fell upon a conductor they caused it to emit little sparks. Such a thing as that we experimenters had not imagined possible. We had never thought that a luminous field would be strong enough to excite sparks when absorbed. FitzGerald might have thought of it if he had interpreted his expression in terms of energy numerically. He had not done that, none of us had done that, but he perceived the strength and beauty of Hertz's result, and in 1888, at the British Association meeting in Bath, he called the world's attention to the fact that Maxwell's electromagnetic waves had at last been pro-

duced; not only produced, but detected, and detected by their extraordinary amount of energy sufficient to emit sparks.

After that, progress was rapid. Hertz's discovery was first understood and made notorious in this country. It never caught the ear of the public, it was not taken up by the newspapers, but it could not fail to arouse attention through the whole of the scientific world. Hertz showed that Maxwell's theory would account for his radiation in every detail; he made a map of the process by which the radiation was generated in an electric oscillator, that is, he mapped out the lines of force during every phase of an oscillation—the beginning, the quarter of an oscillation, half of an oscillation, three quarters, the complete—and these maps of lines of force were published in *Nature* when I translated his paper into that journal in February, 1889. See Vol. 39, p. 451. They could be shown in action on a kinematograph.

The only method of detecting them at first was the scintillae which they produced. I found another means of detecting them by two knobs in loose contact in the circuit of a battery and galvanometer, or again in any form of loose joint and a telephone. This was the coherer principle, subsequently made more practicable by Branly in France, who found that the resistance of the metal coating smeared on paper, or a tube of iron filings, fell suddenly when a spark was taken in its neighborhood.

Now the era of scientific discovery was nearly complete. The rest was what happens when any application is made of science on an extensive scale. A multitude of ingenious inventors combined their ingenuity and experience to apply the process on an engineering scale and to improve it out of all recognition. In 1894, I showed that Hertz's waves, combined with a Branly detector, could be used for sending and receiving messages in the Morse code by the emission and detection of waves from an electric oscillator, a signal or series of waves being emitted and detected at every spark.

About the same time, or soon after, Professor Righi took the matter up and, in Italy, Senatore Marconi began applying the same process privately in his father's garden. In 1896, he came over to this country with an introduction to Sir William Preece, chief engineer to the Post Office, aroused his interest and enthusiasm for this method of signalling, and secured his cooperation. No doubt he encountered many difficulties, not only scientific and engineering but also financial; but he persevered and won through, and to him must be attributed the great success of wireless telegraphy. Before his patent was published, I perceived that something more would be wanted; that as stations multiplied there would have to be selection, and that tuning was necessary, not only to give selection, but also to give sufficient sensitiveness. One station could be worked upon its own wave-length, by a receiver with capacity and self-induction attuned to that rate of vibration. Such a receiver would be very sensitive to one length of wave, and would exclude all other waves. This was patented in 1897, and was regarded afterwards by the courts as the bottom patent for tuning; it was extended by Lord Parker for a total period of 21 years, and for the last seven years was purchased by the Marconi Company. Other improvements were made, too numerous to go into. Marconi's special kind of radiator was an elevated aerial connected through a spark gap to the earth. He was thus able to reach great distances, because the waves oscillated in a vertical plane, so that the electrical vibrations were not wiped out, as they might have been if they had been horizontal, by the resistance of the earth and the sea-water over which they went.

Then came another striking discovery, which must be credited to Mr. Marconi working with unexampled energy on an

extensive scale. He arranged for a large sending station in Cornwall, and travelled across to America to see if he could hear the signals in Newfoundland. I imagine that the scientific world must have been against him in this enterprise, since the waves could not penetrate the substance of the earth, and could not apparently travel round it to reach America. They would apparently travel in straight lines. But enterprise was rewarded, and the signals were heard: only three dots signifying the letter S; that was the arranged thing to be sent. It was enough: it began the series of transatlantic communication. There was something in the earth's atmosphere, an upper layer postulated by Heaviside, as an effect due to the solar radiation in ionizing the upper air, which caused the upper air to act as a kind of mirror, and make the whole earth into a whispering-gallery, so that waves impinging on the layer no longer went straight, but curved round until they reached the Antipodes; so that waves sent out in this country could be heard ultimately all over the surface of the earth. When I say "heard" the waves could not be heard; they make no impression on our senses until they are received by a suitable and attuned apparatus, when the high frequency electrical disturbance is transmuted into the low frequency mechanical disturbance that we call sound. No sound travels from the distant station to the receiver, nothing but ether waves which travel with the velocity of light; so that they reach the whole earth simultaneously. But at the receiving station they are converted into sound energy, and then operate on a telephone.

So far all signalling had been of a spasmodic or discontinuous character. A short series of waves was emitted by each spark, and it was by a succession of sparks that messages were sent. There was no continuity in the waves themselves. But many people perceived that it would be an improvement if, instead of generating a jerky series of independent trains of waves, we could generate a continuous wave at the sending station, so that the signals might consist of modifications or modulations in its amplitude, which modulations might recur with a frequency of their own after the fashion of group waves. To use an acoustic analogy, the method hitherto in vogue had been analogous to signalling by strokes on a bell; whereas what was aimed at was to get something more like organ notes, which would be continuous except when modulated by some kind of keyboard.

So far as I know, the first method of achieving this was the outcome of an experiment by Duddell with an electric arc as part of a tuned circuit. The circuit had a capacity and self-induction in series with the arc. The arc acted very like the blast of air on the lip of an organ pipe, giving an irregular flutter or disturbance which might be made periodic by a suitable resonant cavity, the resonant cavity or organ pipe itself being represented in the electrical case by the self-induction and capacity, that is, by the inertia and elasticity of the circuit. So long as the circuit was not interfered with, the note emitted was of a uniform tone; but by means of a key the self-induction or capacity could be varied, and thus the note emitted could be changed. In that way with a few keys Duddell was able to carve the continuous wave into an imitation of the national anthem or any other well-known tune. Duddell's arc, however, only responded to slow vibrations or long waves; a big self-induction and capacity were necessary, and the arrangement was not applicable to the extremely high frequency needed for an effective sending station.

Poulsen, however, improved the arc by immersing it in hydrogen gas under various pressures, until he had got an arc of really high frequency, which he patented in 1903, and thereafter used it for generating continuous waves of a

frequency such as would generate radiation.

Then came the question of receiving such waves. The thermionic valve was known as a rectifier, that is to say, it transmitted a current in only one direction, because it conveyed the current by the flight of electrons in a partial vacuum. Every vacuum tube acts as a rectifier, since it only transmits the current in one direction. Fleming perceived that this rectifying action of a partial vacuum could be employed as a detector of ether waves, and so patented the vacuum valve as a detector in 1904. It was used at first for the discontinuous system of spark signalling. The unrectified pulses were far too rapid to affect a galvanometer, or even a telephone; but when rectified, so that only half of each wave was employed, the pulses could act in groups, and each group could cause a sound in the telephone, so that if the groups followed one another in regular succession they could cause a musical note whose pitch depended on the frequency with which the groups succeeded one another.

To get the groups out of the continuous wave Fessenden devised the heterodyning system of receiving, that is to say, he superposed on the received wave another wave of nearly the same frequency, so that it would beat with the first. The actual vibrations of neither wave can be heard, but the beats, which represent the difference of the frequencies, are much slower than the generating waves, and therefore come within the range of audition. The beats may, for instance, succeed one another at a thousand a second, whereas the generating waves had a frequency of a million. By this combined plan of heterodyning and rectifying a modulated continuous wave to be received, no matter how complex the modulations were, it was possible to superpose upon a carrier wave the modulations of a human voice applied to it by a microphone and then these complicated modulations could be received at the distant station, and the tones of voice reproduced. This was the beginning of wireless telephony, which depends upon emitting and receiving the modulations of a continuous wave.

But the amount of energy received at a distant station was small, and accordingly the voice was very feeble. But De Forest introduced a grid into the valve, giving it three electrodes instead of two, and supplied the valve with a local high tension battery, so that a stream of electrons travel from cathode to anode, passing the grid on the way. If the grid was not supplied with the pulsations of the received wave it would sometimes be positive and sometimes negative in potential. When it was positive it would help the electrons up on their way; when it was negative it would repel them and beat them down. Thus it stood in the middle of the traffic like a policeman and regulated it, sometimes helping it on, sometimes stopping it. But the energy of the traffic does not depend on the policeman; he merely regulates it. So it is with the grid. The energy of the triode valve is determined by the local battery, and may have any value you please. But the regulation of it, that is the modulation on which signals and voice depend, are determined by the grid, which carves the otherwise continuous traffic into an intermittent stream, in accordance with the fluctuating potential of the grid. So that, although the grid is supplied with very small power, its influence in regulating the traffic is considerable; and the power derived from the valve is thereby regulated in accordance with the received wave, but has a power depending only on the local battery. It acts, in fact, as a relay, putting fresh energy into the disturbance, but not otherwise interfering with it. The electrons are so docile that they follow every fluctuation with precision, so that every feature or tone of

the voice is accurately reproduced, however much it be magnified. That is the beauty of the three-electrode valve; it magnifies without appreciable distortion. There is no distortion in the ether of space, and accordingly the feeble fluctuations imposed on the wave by the voice at the sending station can travel any distance across space without injury, except that they become weaker; and then these residual fluctuations can be magnified up in amount, still retaining their features, until they are capable of actuating a loud-speaker and being heard all over a hall. If the magnification is being pressed to extremes, a little distortion does enter in, not because the ether has any deleterious effect, but because a certain amount of matter is introduced into the circuit, which has the usual imperfections associated with matter; and thus, though the magnification that could be used is very great, it is not infinite.

Next it was found that the valve could also be used for generating continuous waves, at the same time enhancing their power enormously; so that a talker at the microphone could have the modulations of his speech magnified till they were represented by great electrical energy, which then emerged as ether waves from the aerial, and travelled to a distance, where some trace of them was picked up by another aerial, again magnified, rectified and transmitted to the ear. In that way it became feasible to transmit speech or music to great distances. This was in 1913.

Four years later the remarkable property of quartz was utilized. A crystal of quartz, if squeezed, becomes positive at one end and negative at the other, this being the kind of electrification produced by pressure applied to the peculiar structure of the crystal. This effect is reversible, so that when it is electrified it constricts as if squeezed. Quartz thus furnished an intermediary between mechanical and electrical vibrations. The pressure applied to quartz was mechanical; the electric effect resulting was etherial. The two being reversible, there was a possibility of transmuting an ether wave into a sound wave, or *vice versa*. Quartz could be used either for sending or transmitting. A thin plate of quartz would have a high rate of mechanical vibration in the longitudinal direction. An electrical vibration of the same frequency applied to it would call out this very high frequency sound vibration. It could not be heard, it would be supersonic, but it could produce various effects. These effects have been studied of late years by R. W. Wood, of Baltimore, and other people. The facts are astonishing, and have introduced a fresh department into science called supersonics.

Eccles, however, proceeded to use the vibrations of quartz as a transmitter for electrical waves of steady frequency. He regulated the frequency by a tuning-fork, adjusted once for all to the frequency desired. He then caused the fork to operate on a piece of quartz so as to generate electrical vibrations of the same frequency. These could then be magnified up, transmitted to the aerials of the Rugby station, and so send out waves of enormous power all over the earth, with a precision of tuning hitherto unequalled, so that an operator at a distant receiving station with an accurately tuned receiver could do anything he liked with them.

Broadcasting on a large scale now became possible. In 1920 it was initiated in the United States, and in October, 1922, the British Broadcasting Company started its career in this country. Later it became a government institution, the British Broadcasting Corporation, and, under the management of Sir John Reith throughout, made itself responsible for transmitting speech and music from a number of stations on different wavelengths to all the houses in the British Isles (and far outside them) who would pay for a license.

CHILDHOOD IN THE MACHINE AGE

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OUR country's most precious natural resources are not best represented in subterranean acres of coal beneath the soil of Pennsylvania or Virginia; nor in the fountains of oil that spurt incessantly from the great gushers of the southwest; nor yet in the glittering minerals that lie deep in the heart of the Rockies; nor in the iron-ribbed hills washed by the waters of Lake Superior. Significant as all this natural wealth is to the progress of an industrial era and a machine age, it shrinks astonishingly when weighed in the balance with that greatest of all natural resources—the childhood of the nation.

For fifty years and more—indeed, ever since the later decades of the last century, when the talons of industrialism began first to bury themselves in the brawn of our human society—we have been witnessing the evolution of an age wholly unlike any previous condition that the race has ever achieved. We have beheld the tapping and the exploitation of the vast mineral and natural treasure of America as men, aflame with the passion to create and enjoy new wealth, have turned their genius into these channels. We have seen the development of factories, industrial establishments and commercial agencies to devise, manufacture and sell myriads of new kinds of merchandise. We have witnessed the construction of a labyrinthine distribution system to transport to the remotest corners of the nation new products and new commodities. We have witnessed the steady withdrawal of the population from the villages and the open country, and its concentration in great urban centers in order that human pawns might find place as cogs in the grinding gears of the industrial machine. Increasingly, we have applied ourselves to the building of a novel civilization reared upon the sure and unfailing foundation of coal, iron and, latterly, oil.

Meantime, what of that other great natural resource—childhood? Have we been as eager to develop all its inherent possibilities as we have those of steel, or of electricity? Have we improved and bettered its status commensurately with the improvement that we have brought about in fifty years, say, in the smelting of iron, or in the perfecting of the internal-combustion engine? Oh, yes, we have builded school buildings architecturally and intrinsically second to none in any country on the globe. We have levied and expended for the equipment and maintenance of them more dollars out of the public tax money than for any other enterprise of government. We have trained teachers, employed experts to supervise them, and provided pensions for them after their period of usefulness is ended. As the changing demands of our culture and civilization have made imperative a more elaborate school, we have introduced a whole galaxy of new subjects into the curriculum. We have established a system of secondary education for the children of the masses which is unique in America, and with which there is nothing even remotely comparable elsewhere on the face of the earth. We have compelled all children to attend the lower schools throughout the pre-adolescent years, and have urged and made so attractive attendance in the secondary school, during the early adolescent years, that enrolment in our high schools has multiplied itself faster than we could provide the housing. Side by side with our

great public education service, we have planned and brought into existence health centers, medical inspection, nursing and dental service, playgrounds, athletic fields, gymnasiums, scouting activities, and a score of other agencies designed to minister to the needs of the physical growth and welfare of a junior population which at the present time numbers no less than 45 millions. Oh, yes! We have taken good care of childhood! We have kyanized it, preserved it, conserved it! Look at all the money we are pouring into education and training!

But have we?

Here are the facts:

Of the 45,000,000 children in America under 18 years of age:

6,000,000 are undernourished! These are they who, as the years pass, will fall prey to all manner of infectious diseases, including tuberculosis, because they will lack the physical stamina to resist disease. These are they who will contribute most liberally to swell the ranks of postponable deaths—about 500,000 annually at present, or 42 per cent. of all deaths—with a gross annual economic loss to society of more than a billion and a quarter of dollars.

1,000,000 have damaged hearts! Ten years ago, and more, the mortality statistics from the registration area showed tuberculosis—the great white plague—to be the chief cause of death in the United States. Today, heart disease stands at the head of the list! These 1,000,000 children, with hearts damaged by the childhood diseases and their after-effects, are they who will, as the years pass, be reported as those who "died suddenly" of heart disease, for it is a well-known though little appreciated medical fact that the great cause of heart disease and fatality in middle life is to be found in hearts that have been damaged in the early childhood years.

1,000,000 have defects of speech! These are they who will find themselves sharply limited in their vocational prospects, whose personalities will be poisoned from the earliest schoolroom years, and who are being doomed to a lifetime of rebellion, suspicion, and not infrequently of moral obtuseness and obliquity.

675,000 are recognized and branded in the community as "problem children." These are they who in childhood are maladjusted to their homes, to their mates, or to their general milieu. They include the timid, the lazy, the disobedient, the dishonest, the temperamental, the emotionally uncontrolled, the "bad" children, the incorrigible, the sex-dominated, and a host of others who, unless their social, personal, or character abnormalities are corrected, will, as the years pass, grow up to fill our almshouses and jails and prisons and asylums, or, escaping that fate, will swell the ranks of the "queer," the neurotic, the unstable, the profligate, and the prostitute.

500,000 are dependent! These are they who, denied the right of every child to a home and parents, must be reared in orphanages, foster homes and institutions. As the years pass, some of these will pull themselves up by their boot-straps and will climb into positions of honor and respect in the community. Others of them will be confirmed in habits and attitudes of waywardness, sullenness, introversion, moroseness, inferiority, anti-socialism and worse.

450,000 are mentally retarded. This is a very conservative estimate, representing one per cent. of the total junior population. The mentally retarded include all grades and degrees of the backward, from the "repeater" in the schools to the lowest-grade idiot in the institution. Subjected to the same educational regimen as normal children, the mentally deficient at best only waste their time in the schoolroom, and at worst develop all manner of maladjustments and grow up to be social and economic liabilities in the community.

382,000 are tubercular. These are they who are in the fell grip of what turns out to be in more cases than not a losing struggle with the great white plague. While our educational measures have brought about a steady reduction in incidence of this dread disease among adults, they have been less successful in the younger groups. Tuberculosis kills as many school children today as it did two generations ago. It is the fourth most common cause of mortality during infancy, and in the 10–14-year period it ranks first. 150,000 people in the United States have been crippled by tuberculosis of the bone alone.

342,000 are hard of hearing, and 18,000 are totally deaf! In the life game, these are they who by the very nature of their handicap must be denied admittance into many vocations, will be restricted sharply in their social contacts, and will be inevitably prevented from developing some of the fundamental traits of character and of personality. Very commonly they will develop quite decidedly negative ones.

300,000 are crippled! Infantile paralysis, tuberculosis and other diseases are taking a toll in leg and limb that shows no evidence of diminution. In fact, the ratio of crippled children to the whole population remains about the same from year to year. This is one of the tragedies of our age.

200,000 are delinquent! This includes only those who pass through our juvenile courts in a single year, and takes no account of the far greater number of delinquencies handled by the police, nor of unapprehended delinquencies. In 1927, about 1 per cent. of the children of juvenile court age in the United States, for the area in which statistics were available, came before the courts as delinquents. These are they who in the years to come will furnish most to our national quota of racketeers, criminals, scoff-laws, prostitutes, gangsters, hold-up men, *et al.*

And so the drab facts run! They tell a disconcerting tale relative to American childhood. Ten million strong, the great army of the underprivileged, the defective and the delinquent, are hammering at the very gates of the citadel of our civilization. They are demanding those inalienable rights that must in the future be vouchsafed in increasing measure to all children: health, the correction of their deficiencies, protection from the by-product evils incident to our social and industrial organization, and the establishing of such an intelligent and far-seeing program of prevention touching every phase of child welfare as may be worthy of a great and enlightened people.

With the purpose of setting in motion such a program of conservation in the realm of childhood, President Hoover, somewhat more than a year ago, took the first steps in creating the White House Conference on Child Health and Protection, which convened in the city of Washington, November 19th to 22nd, 1930. The President was cogently aware of the multiplicity of problems of child life and training that a changing society has brought to the forefront. In a machine age and in an industrial era wherein human life has been literally transformed into new terms and new values, it was apparent to him that there must be a huge body of factual material with reference to child hygiene, child guidance, home training, dependency, delinquency, and the like which, if assembled by experts, could be turned to valuable account in the shaping of a wholly new science and a new gospel of child welfare and training. It was apparent also that the rank and file of people have obviously not kept pace in the rearing and training of children with the scientific developments in the general field of child health and welfare, and that there was need of a national survey to focus public attention upon the newer knowledge.

Taking its origin from a small group of well-known men and women to whom the President first made known his wishes, the White House Conference on Child Health and Protection was expanded to include some 1,200 experts in related fields of child welfare. These workers were headed by the President's planning committee, under the chairmanship of the Honorable Ray Lyman Wilbur, Secretary of the Interior, and the vice-chairmanship of the Honorable James J. Davis, then Secretary of Labor. Altogether, a total of some 170 different committees and subcommittees devoted approximately a twelvemonth to research and investigation in preparation for the conference. These 170 committees represented seventeen divisions, as follows: Three in medical service; three in public health service; seven in education and training; and four in the handicapped. Each committee and subcommittee was under the immediate chairmanship of a nationally prominent expert in the field represented by the specific activities of the group. There is no phase of child life which was not covered by some or another of these professional groups. Men and women all over the United

States and the dependencies gave willingly and gladly of their time and skill in the name of childhood. There was no congressional appropriation behind the project; there was no political engineering nor control. Every member of the conference took care of the expenses he incurred incident to the work. Even the invitations from the President to attend the general conference carried each its two-cent stamp! Generous contributions from well-wishers made possible the printing of the various reports.

"This task that you have come here to perform," said the President in his opening address to the conference, "has never been done before. These problems are not easily answered, they reach the very root of our national life. . . . There has not been before the summation of knowledge and experience such as lies before this conference. There has been no period when it could be undertaken with so much experience and background. The nation looks to you to derive from it positive, definite guiding judgments. But greater than facts and the judgments, more fundamental than all, we need the vision and inspired understanding to interpret these facts and put them into practice. . . ."

The facts and judgments presented by the various research committees, and the ways and means proposed to insure their being translated into practice in the homes and communities of America, justify the modest conviction in the minds of the 1,200 members and the 2,000 official delegates and representatives in attendance that the White House Conference on Child Health and Protection was the greatest philanthropic congress of willing workers in the cause of childhood ever assembled on the globe. When made finally available to parents, teachers, social workers, physicians, judges, *et al.*, the reports of the 170 committees will fill some fifty volumes. For four days the beautiful auditoriums of the city of Washington —Constitution Hall, Continental Hall, the Hall of Nations, the Assembly Room of the American Red Cross building, the Corcoran Art Gallery, the auditorium of the National Academy of Sciences, and the auditorium of the Interior Building, not to mention innumerable hotel foyers and dining-halls —were thronged with a multitude of men and women who rank among the leaders in child welfare procedures in this country. The President and Mrs. Hoover opened the White House for a most charming and delightful reception to the delegates.

In attempting to abridge the more important findings and recommendations of the conference, one can but select a few of the high lights. One finds the committee on prenatal and maternal care directing the attention of the conference to the status of the mother before and subsequent to child-birth. Surely it is not an unreasonable recommendation that every woman should be safeguarded during these months by expert care and attention from nurses, dentists and doctors, under the supervision of trained obstetricians, and that in every home and in every hospital this care should be available whether in rural or urban communities, and for all racial, economic and social groups. Our mortality rates from accidents and complications of child-birth are still shockingly and inexcusably high. As a nation, we have barely even made a beginning of safeguarding the mother during pregnancy. Only a small portion of women receive adequate prenatal, maternal and post-natal care. Many practical nurses are ignorant, untrained and a menace to both mother and child, although it is also a fact that some practical nurses, self-taught as they are, are capable and efficient in their work, and have had considerable experience in their communities. The

mid-wives as a group are far below the standard of Continental mid-wives, as they have always been. In the progressive European countries mid-wives undergo two or three years of training, and are subsequently kept under direct control and supervision of well-trained obstetricians.

The committee on medical care for children finds very little evidence of any great number of parents who see to it that periodic health examinations are made of their children of pre-school and school age. The general practitioners of medicine report parents to be almost universally neglecting this precaution. Here is a situation admittedly greatly in need of remedying. The pre-school years, before the child is brought into contact with the school medical and inspection service, are years in which incipient major defects find footing in the child organism. Diseased tonsils and adenoids, poisons and weakness resulting from the children's diseases, and the ill-effects of poor nutrition run riot in the pre-school period, injuring and slaying here and permanently disabling or debilitating there. Adequate health service would prevent these disastrous losses in the still trackless and uncharted wastes of the pre-school period. While our infant mortality rate has declined gratifyingly in the past fifteen years, it is still higher than it is in New Zealand, Norway, Sweden, Australia, Switzerland, the Netherlands and the Irish Free State. The lowest mortality rate in this country is found among the babes of mothers born in Russia, mostly Russian Jews.

There are in the United States sixteen millions of children under the age of six years, and the committee on the infant and pre-school child points out that these first six years of life remain largely still unchanged. Parents too commonly labor under the conviction that the pre-school child "just grows," and that care of him is largely a matter requiring no particular skill or knowledge. From a fairly wide sampling of the homes of four-year-old children, the committee concludes that physical care is on a more effective level than is training for mental and social adjustment. In fact, it was agreeably surprised to find the physical standards in the families surveyed higher than had been anticipated would be the case. Typically, the four-year-old sleeps eleven and a half hours; drinks from one and a half to two and a half pints of milk a day; has cod-liver oil in winter but not in summer; eats occasionally between meals; is bathed daily in summer and twice a week in winter; owns and uses a tooth-brush; has had a medical examination within a year; is punished by the mother rather than the father; is spanked from one to four times a month; plays out of doors from five to eight hours a day; and the chances are one to three that he has been inoculated for diphtheria, one to four that he has been vaccinated, and about even that he goes once or twice a month to the movies. In few cases does the family have contacts with a social agency, clinic, or public health nurse. The level of practice in matters of health in these homes is related closely to the socio-economic status of the family and to the educational background of the parents. In calling attention to the need of assisting and encouraging parents in the exercise of their educational function, the committee sagely asserts that the parent himself is a teacher as well as a parent, and needs help quite as much as do professional workers with children.

The committee on communicable disease control finds that no fewer than three millions of cases of communicable disease are reported annually in this country. Obviously many more are never reported. A million and a half of these diseases occur in children, and

they furnish about 20 per cent. of all deaths. In addition to the fatalities, blindness, damaged hearts, weakened kidneys and many other disabilities follow typically in train after an epidemic of the children's diseases. Infantile paralysis and tuberculosis together succeed in crippling from a half to three fourths of the whole group of cripples. The time is not long past—indeed is not yet entirely past—when mothers were heard to say: "I want my Tom to catch measles and scarlet fever and chickenpox and all the rest, while they are going the rounds. I don't want him to grow up and have to get them then!" These diseases have recognized and high mortality rates, and are followed so frequently by very serious complications that it is in the interest of economic and humanitarian motives that the periodic sway of the communicable diseases shall be speedily broken. Isolation and quarantine have failed, partly because the real mischief has been done before the first cases in a community are recognized clinically, and partly because the public has been disappointingly indifferent to the rigorous acceptance of the regulations. Through a wider extension of public health nursing into home, health center and school; through prompt reporting, adequate isolation, adequate hospitalization, prompt investigation and control of carriers; and through consistent education of the community, very much can be done to improve conditions. Such a program will mean well-trained, full-time health service for federal, state, urban and rural units, with proper assistance whenever and wherever needful. This is neither impractical nor unrealizable for every community in the land.

The committee on milk production and control finds that every man, woman and child in the United States consumes on the average a little more than one pint of milk a day throughout the year, and that this amount is slowly increasing though it is still well below the optimum. As a nation, we are far from being as insistent in our demands for pure, pasteurized milk as we are in some localities. Surveys made in 430 American cities indicate that the quality of retail raw milk tends to improve as the size of the city increases. In the five-year period from 1924 to 1929 there occurred 258 outbreaks of communicable diseases that were traced to contaminated milk, with some 11,000 individual cases and 371 deaths. Two thirds of these epidemics were of typhoid fever. The incidence of these outbreaks occurring in small country towns, rural sections and cities under 35,000 population, was much higher than in the larger cities. Fluid milk is still a strong offender in the transmission of disease, due to inadequate public health supervision of the milk supply which aggregated, in 1926, more than 15 billions of gallons for the whole country. For these reasons it is imperative that the coordinated attention of all state and local agencies, including public health authorities, agricultural departments, and agricultural, extensional and educational organizations within the state or community, shall be given to all factors relating to the sanitary production and distribution of this most universal and essential of all foods.

Is family life in America threatened? This is a query raised by the committee on the family and parent education. The thesis is suggested and defended that machine-age culture is not inimical to the evolution and enjoyment of the best of family values. It is patent that many transformations are being wrought in the family by our industrial civilization. In an age of specialization, increased technology is diminishing the satisfactions and the interest in work. Thus the stability of employment is affected adversely. Factories are drawing workers from the rural and settling them in the urban communities. Child-

less marriages become more common and the percentage of homes owned by their occupants diminishes with urban living. Single-family dwellings decrease and tenement and apartment dwellings increase. The ratio of married women gainfully employed outside the home is raised markedly in such circumstances. Illegitimate births and divorces increase with the size of the community. Buying the living has replaced producing it in the home. Other results of this change in our fundamental social organization include the location of homes around factories, less space per person, less privacy, less play-room, less family entertaining, more dependence upon outside sources of amusement, less real family life.

Notwithstanding these circumstances, it would be fairly easy to make use of the changing economic factors actually to strengthen the bonds of the family, if society were to vouchsafe as much time and deliberation to the study of the situation as it is willing to employ in the solution of other important economic difficulties, such, for example, as those touching trade, the exchange of commodities and the like. It is possible—indeed, the reasonable standards are known already—to set up enlightened standards of housing; to encourage and stimulate wide home ownership; to provide safe and attractive recreative centers and opportunities; to establish and guarantee the continuance, with rational safeguards, of a reasonable income that shall be sufficient to maintain the family in comfort and contentment; to provide medical and nursing service that is not prohibitive; and to better adjust the home and extra-home activities. The time is adjudged right for laying the foundations of a new science of the family. To this, the findings of home economics, sociology and of child psychology and mental hygiene can contribute tremendously. Parent education becomes of supreme importance in any such new science of the family, and such agencies as churches, religious and lay educational organizations, community centers, health clinics, visiting nurses, social workers and visiting teachers, may be expected to assume large importance in acquainting parents with the needs and potentialities of their children and of the family life together.

The family is basal to civilization. None of its inherent functions can safely be removed from it. Whenever outside influences appear to be endangering them or it, there is instinctive resistance. For parents there is no substitute. It is through them and his contacts with the family that the child finds security, love and protection. Well-adjusted parents are essential in providing him with a wholesome emotional background. At its best, the home serves to transmit culture, aesthetic tastes and intellectual stimulus. From it the child derives his social insights, his fundamental attitudes and the foundations of religion. To preserve the institution of the home and to dignify and ennoble it must be one of the potent objectives of government and of education.

In its report upon the child of school age, the committee on the school child finds a grimly bright picture in the circumstance that while adult mortality from accidents has increased 32 per cent. within the last seven years, the accident mortality of children has remained stationary in spite of the increase in population. It is a tragic commentary upon our times, however, that in the year 1929 no fewer than 18,000 children were killed in accidents. This was nearly a fifth of all accidental deaths for the period. Strong emphasis is placed by this committee upon the ways and means of promoting both the physical and the mental health of the child in the schoolroom. Obsolete and insanitary buildings are denounced; the future necessity for an all-year program of recreational activities is stressed; the

still too common practice of assigning and requiring home-work in the elementary grades is criticized; a summer round-up of all children who are to be school entrants in the fall is called for; systematic and effective health inspection is recommended; Schicking and vaccinating before school is demanded; the importance of correction of juvenile defects whenever they appear is emphasized; and a thorough-going system of health teaching and physical education is outlined in detail. A somewhat new note in education is the insistence by this committee that mental health is quite as important as physical health, and that the attiutdes which a child develops toward his work, his studies, his mates and associates, his country and society in general, are of profound significance in shaping the effectiveness and the happiness of his life outside of and beyond the school. It is the belief of the committee that teachers must be trained to understand the importance of mental adjustments, and to teach children how to think and work and enjoy and appreciate and judge and sympathize and respect and wonder and reverence, quite as well as to multiply and parse.

The committee on vocational guidance finds plenty in our industrial system, as it affects young workers, to criticize and condemn. Blinded by the spectacle of the upper few in our schools who go on to secondary and higher schools, society has failed quite generally to take note of the millions of children who leave school at the expiration of the compulsory period to enter workaday life in the thousands of occupations. Contrary to the recommendations of physicians that no gainful junior employment can be safely begun under sixteen years, and to the growing opinion of employers that eighteen years is a better minimal age, hundreds of thousands of boys and girls under 16 continue to be employed in a great variety of non-agricultural occupations, chiefly in factories. Many of the types of work into which these children enter are physically and morally detrimental and are fraught with high prospect of accident hazard. The length of the factory day for 14- and 15-year-old children is very often fifty or more hours a week, and the wage invariably averages under $15.00 and generally under $10.00. More than 20,000 minors under the age of 18 are injured annually in hazardous occupations. In 13 states, 1,100 were killed or disabled permanently in industry within a single year. More child workers are engaged in agriculture than in all other occupations, many of them being either hired out, or else migrant workers with their parents under a contract system. In this type of employment, work is hard, hours are long, exposure to dampness and cold is frequent, the cramping positions in which plastic bodies must be maintained over long periods are fatiguing and deforming, and the rights of formal schooling are seriously infringed upon.

The whole question of vocational guidance and protection from exploitation in the occupations is greatly in need of solution. Testing; counselling; exploratory study of the occupations; revision of the school curricula, in junior and senior high schools, to include guidance; study of occupations in all continuation schools; the devising of placement and supervision machinery for young workers; and the making available of scholarships and aids for keeping boys and girls of needy families in school—these are among the recommendations made by the committee. The needs of such vocational education and counselling are not yet widely enough appreciated by the general public, which is not fully aware of the far-reaching changes in our industrial system that have been recently coming to pass. Among these changes are the fol-

lowing, every one of which indicates the distinct necessity for preparatory adjustment in the worker before he enters it: new machine methods of production and distribution; increased mechanization of even the simplest manufacturing process; the introduction of the automatic telephone, telegraph, bookkeeping and billing machines and tabulators; self-service restaurants; power-driven farm machines, etc., etc.

In the matter of protecting children from exploitation, progress has been very uneven. Some states have developed high standards of protection for juveniles; others have been content to maintain low standards. Children in the latter sort of state are denied equality of opportunity for health, education and play. In the former type, the manufacturer must compete with the products of cheaper labor in the latter type. The whole problem is greatly aggravated by the extreme mobility of our modern citizenry, which results in the migration of workers from low-standard communities into communities possessing high standards, thus hampering civic and economic progress. True democracy can not be realized until every one has a fair chance, a good start and an equal opportunity. The institution of child labor denies all three of these boons to the children of the poor.

The committee on recreation and physical education finds that, barring practice in a very few nursery schools, there is almost no attention being yet vouchsafed to the younger child along the line of physical education and constructive recreation. Though the pupil of school age is somewhat better provided for than his younger brother, he is still too largely neglected. Only a few states permit the use of school grounds after school hours. Many school sites are being continually encroached upon by the ever-expanding industrialism which raises the value of land and so reduces the size of playgrounds and school yards. Innumerable buildings in our cities have no school grounds worthy the name. Conditions in many non-urban districts are only slightly better. There is little organization of recreational activities; little curricular time devoted to them; little stimulus to a permanent interest in them, and little attempt made to provide desirable coaching and training through the wise classification of pupils according to their specific needs or defects. It should be deemed to be as proper and inherent a function of the school to promote normal physical growth and structural development, neuro-muscular coordination, emotional expression and control, love for and increasing skill in physical culture and activities, and such desirable character traits as modesty, fairness, generosity and loyalty, as to promote knowledge and facility in the conventional school subjects. An enlightened and adequate system of physical education and recreational development must be the proper channel through which to bring these things into being. Fortunately there are many agencies outside the school—private and semi-public—that are supplementing this program. Scouting, summer camps, clubs, associations, community centers and the like are rendering invaluable service in this field. One of the major needs in the building and administering of programs in recreation and physical culture is that of trained leadership. Another, equally important, is that of educating the public generally in the significance and in the objectives of this program.

The committee on special classes desires to disillusion those smug individuals who consider specialized education of the handicapped an educational frill, or a charity, and not a sound public policy. Rather, it is a most sound policy, for by training these unfortunates, society is making them both self-supporting and self-respecting. In one

state, the amount earned by the disabled in the first year after vocational rehabilitation was introduced, over and above that earned in the preceding year, was five times the total cost of the rehabilitation. It is even sounder economy to train the handicapped child than it is the handicapped adult, for he is more plastic and will respond more promptly. The handicapped children in the United States include, among others: 14,000 blind; 50,000 partially blind; 18,000 deaf; 342,000 with hearing impaired to such an extent that they should be taught lip-reading; 1,000,000 with defective speech; 300,000 crippled, and 450,000 mentally retarded enrolled in elementary grades, of whom only 60,000 are in special classes. Most of the 3,000,000 elementary school children who need special class opportunities are still herded in with the rest of the school population, with undifferentiated types of study and work. Such special classes as exist are limited chiefly to the cities, and to only a few of them. In the smaller communities and rural districts this problem has hardly yet been even touched. Guidance of an exploratory or prevocational sort, of which these child types stand so sadly in need, is the very common exception everywhere. These children—especially the mentally slow—idle or fret along at tasks which they can not assimilate, and develop as by-products of their failure mental attitudes of resentment, inferiority, stubbornness and often rebellion. They are doomed by the very nature of their deficiencies to be failures in the conventional classroom; in a special classroom most of them will succeed gratifyingly. Far from being foreordained, this tragedy of failure is preventable.

The gifted children, of whom there are a million and a half in the schools of the United States, present another phase of the same problem. Left in the conventional classroom, they stagnate, lose interest, develop slothful habits and attitudes, and may end by dropping out of school prematurely as cynics and malcontents. Many gifted persons, it should be recalled, are in our penitentiaries; many more of them are in the community, employing their talents selfishly or actually detrimentally to the common good. Yet it is the gifted few who must be counted on to supply our inventions, manage our great enterprises, create our art and literature, conserve and control our wealth. It is the height of social and economic folly to miss-fire in our handling and training of the more gifted among the rising generation, forcing them thus into selfish and anti-social fields instead of enlisting them perennially on the side of human welfare and progress.

The committee on youth outside the home and school presents, among many interesting and valuable findings, none more so than those concerned with commercialized amusements in their effects upon juveniles. The drabness of the adult worker's life in an ultra-machine age leads him to seek "lively" amusement as a reaction to the monotony of the working hours. The motion picture, our fourth largest business, has become within the brief space of a single generation the chief means of recreation. Two billions of dollars are invested in the industry in the United States, and the output of positive film reaches a billion feet per annum. This is 85 per cent. of the world's production! The daily clearance of film through the various exchanges in this country would encircle the entire globe. The 22,600 exhibiting theaters have a seating capacity of 11,300,000 persons. Every man, woman and child in the United States on the average attends a moving picture performance once a week. This is almost half the entire world audience of 250 millions of people a week. In the general field of commercial amusements, the dominant motive is profit rather than public service. Coney

Island, in New York City, for example, alone entertains more than 20 millions of persons a year. Slightly over half the expenditure for amusements in New York City every year goes to the movies, the theaters, the cabarets and the vaudeville; the other half goes to dance-halls, pool-rooms, amusement parks, carnivals and steamer excursions and the offshoots of these. One finds the promoters of amusement projects in large measure making their own laws and establishing their own standards. These laws and standards are often diametrically opposed to those which parents and the educational world generally are striving to set up and maintain. From 50 per cent. to 75 per cent. of the patrons of these institutions are children and youth drawn from the working-class parents, who obviously have fewest resources within themselves. Children's programs of amusement are still unheard of in most communities. Commercialized amusement resorts are apt to have a fringe of criminal or near-criminal hangers-on—prostitutes, gamblers, dope-fiends, bootleggers and the like. Such potential influences are distinctly dangerous to the rising generation. Exactly what relationship exists between commercialized amusements on the one hand and juvenile delinquency and crime on the other hand, is still largely a matter either of conjecture or of prejudice. The weight of responsible opinion, however, unquestionably assigns a significant positive relationship. One of the reports of the New York crime commission, in setting forth the results of a survey of delinquency in one of the districts in Kings County, asserts that "the low-grade pool-room is the chief hang-out for the crook, and more burglaries among boys between the ages of 16 and 21 are concocted there than in any other single place."

The committee on dependency and neglect, after affirming its faith in the importance of maintaining the dependent child in his own home whenever and wherever possible, presents data to show that, in 1929, 33 states, through mothers' aid legislation, were able to keep 220,000 children, who would otherwise have been placed in foster homes, in their own families, the gross expenditure for this purpose being in excess of 30 millions of dollars. Without this assistance, many a mother would have worn herself out in a desperate effort to earn a livelihood for her children and to keep the home together, paying for this heart-rending labor with later ill-health or break-down, and being conscious throughout the whole trying time that personality and behavior problems were arising in her children for whom no adequate home care and correction could be provided. Supplementing this highly important and economically sound principle of state-aid to widowed or indigent mothers is the work of the voluntary family welfare agencies, which in 1929 provided aid to 380,000 families containing 750,000 children, and of the more than 600 day nurseries of the country which provide daily care for some 25,000 children of working mothers.

The whole problem of dependency involves many complex factors. One has to do with illegitimacy. In the registration area in 1928, 42 states reported 63,942 born out of wedlock. The fate of such children is a hazardous one. Abandoned or renounced by their mothers, spurned by their fathers they become the flotsam and jetsam of almshouses, orphanages and homes. Unmarried parents should be required to assume their responsibilities just the same as married parents, although marriage and cohabitation may not always or even generally be advisable. Another problem concerns itself with the Negro children, among whom the death rate is $\frac{2}{3}$ above that for white children. A whole series of problems revolves about the status and efficiency of the child pro-

tection agencies, of which there are some four hundred in the United States. In the majority of these, protection of animals as well as of children is championed, and the attention to the former is apt to be more assiduous than that to the latter. The staffs of most of these agencies are small, untrained and inexperienced; consequently only a modicum of constructive child welfare work can be done. The staggering totals in our annual industrial accident column present another factor which bears very directly upon dependency, since accidents are likely either temporarily or permanently to remove the breadwinner from the family. On the whole, while there has been declination in some industries, there has been an increase both in the number and severity of accidents in industry, not to mention the absolutely unjustifiable and needless increase in automobile accidents and fatalities. More than 14 thousand children are orphaned annually through death of their fathers incurred while performing their daily work of earning a livelihood. The workmen's compensation legislation, while affording relief in the amount of 150 millions of dollars annually, fails to protect many thousands of workers whose occupations are not included in the list of eligibility. Among railway employees engaged in interstate commerce, and therefore not eligible, there were 1,700 deaths from accidents in 1927. Among the male population generally, violence (excluding suicide) is the highest single cause of death between the ages of 20 and 55 years. Irregular employment, seasonal unemployment and idleness; displacement of human by the introduction of machine labor, and the improving of technical processes which leaves groups of workers without jobs are other complicating factors in our industrial system, and causative factors in the perpetuation of child dependency and privation. Still another major difficulty is the meagerness of the family income. Recent elaborate and reliable research indicates that an ordinary family, if it is to maintain a reasonable standard of living in an American city of to-day, must have a minimum income of from $1,600.00 to $1,800.00. In 12 industries that employed the largest number of workers in 1929, as covered by the statistics of the United States Bureau of Labor, only three reached or exceeded a minimum wage level of $1,700.00. Two fell below that figure by over $800.00. The committee concludes that "the majority of families in this country are living close to the margin of economic want." Innumerable families are living —or existing—well below this margin, as the experience of hosts of social agencies in our cities abundantly testifies.

The committee on delinquency presents some highly significant food for thought in connection with the age-old but ever new problem of delinquency. The virtue of an adequate system of dealing with the juvenile who has strayed from rectitude lies not in punishing, but rather in understanding the causes and drives that have contributed to the delinquency and in seeking by all known means to remove them. The question of juvenile delinquency is assuming major proportions, the conclusion seeming to be warranted that it has not declined as rapidly and certainly as all our efforts to combat and control it would appear to have warranted. Basally, any delinquent act may be interpreted to be the result of some inner stress or inadequacy to which the victim can not adjust satisfyingly. Some of the causes behind these states of mind include lack of love and understanding in the home; "broken" homes, which are found in one third of all cases of delinquents who come before the courts; gang influences of a destructive nature;

school disinterest and failure, arising out of an educational system that has unfortunately laid more stress upon "informing than forming"; the impossibility which many youthful workers feel of finding pleasurableness and satisfaction in their earning life since so many of the jobs in which they engage are destitute of stimulation and the need for creative imagination; narrow apartment life, with little to commend it to the younger in particular; and the deleterious influence of much of our commercialized recreation, etc. Our treatment of delinquency remains in most quarters obsolete and negative. Police fail to differentiate very sharply between children and adults, employing force and fear rather than intelligence and understanding. Juvenile courts fail largely to diagnose waywardness, and content themselves with maintaining discipline in the junior population. Rehabilitation work is sporadic and inefficient. Probation officers are still not teachers so much as they are officers. Corrective and disciplinary institutions remain even to-day largely places of detention where undisciplined or undisciplinable children and youth may be isolated from the community, notwithstanding the inevitable consequence that such segregation will more likely than not serve to increase the maladjustments between the youthful inmates and the outside world.

Finally, parents themselves will have to learn that after all water can rise no higher than its source, and that to whatever degree deceit, double standards, libertinism, dishonesty, insincerity and sham exist in the parent generation, these evils are bound to be reflected in the conduct and character of the rising generation. In the very expressive words of Judge Cabot: "Guardians of the child have the duty to present in their own lives such patterns of honesty, sincerity and courage as shall challenge the child's emulation. In an age when mechanical devices bring distant wonders and the spread of wealth provides ease and comfort beyond our wildest dreams, it is of the greatest importance that all adults realize that by no trickery is the matter of wholesome life produced. It is only in the example of sincere living that the child finds the dynamic impulse for his own wholesome development."

The White House Conference on Child Health and Protection has delved further into the complex problems of the welfare of childhood in the machine age than any group of investigators has ever before undertaken to do. The findings of the hundreds of experts and specialists who have contributed to it will, within the next quarter of a century, exert a profound influence upon much of our educational and social philosophy. Schools, churches, welfare organizations, jurists, parents, teachers, and all other persons and agencies, who have to do with the care and shaping of childhood and youth, will have at their disposal the basal facts and conditions of child life as they are found to exist at the close of the third decade of the present century. They will have also the counsel and the pooled wisdom of the men of medicine, of hygiene and public health, of education, of psychology, of sociology, to aid them in the planning and in the execution of their gargantuan tasks. The conference itself is over. Back into the far communities of the nation its members and workers have returned, carrying with them a new spirit and a new earnestness. The impetus which their research has given to the cause of childhood, and the momentum which their continued efforts to evangelize their constituencies into the new gospel will gather, will go far toward ameliorating the present not altogether satisfactory status of childhood in the machine age.

SAVE OUR WILD FLOWERS

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SUMMER is the time of year when our woods and meadows are gay with wild flowers, at least, *some* of our woods and meadows are. Unfortunately many of them are often raided by people who have driven out from a city or town to spend a day in the country, and others are often swept by fire, started perhaps through carelessness on the part of the same vacationists. The end result is the same—places which should be full of beauty show only devastation and ugliness.

It seems almost impossible to get even well-meaning people to realize how rapidlly the wild plants can be destroyed. There has just come to my desk a copy of a magazine published by an organization devoted to outdoor recreation through mountain climbing and similar activities. Surely, one would think, such an organization should be interested in conservation! Yet the cover illustration shows a couple in a remote mountain meadow, busily engaged in destroying nature's gifts—gathering flowers which could not possibly last until they got them home, but would be sure to wither and be discarded half way down the trail. The comment on this picture in the text reads, "The scenery at this point is one of indescribable grandeur, and tourists made sure to pluck a goodly number of blooming flowers as reminders of their visit." No doubt the flowers were profuse, and it may have seemed as though no harm was being done by the taking of the goodly number which this group of visitors picked; but by the time all the successive groups who go there during the season have picked their goodly numbers, and this is repeated year after year, it will not be long before the place is a barren waste.

The Wild Flower Preservation Society, the American Nature Association and other similar organizations are doing all they can to discourage destructive flower-picking, but public sentiment has not as yet been sufficiently aroused. It will be necessary for every lover of the outdoors to both preach and practice conservation at every opportunity.

One of the most promising plans for saving our wild flowers from complete annihilation consists in arousing the interest of school children in the need for sparing them. There are various ways of accomplishing this, but one of the most successful is to hold contests, in which prizes are offered for the best slogans, or the best posters, which may be used in a campaign for encouraging conservation. The Garden Club of the City of Binghamton, New York, has recently staged such a contest, and an outline of their method of procedure may be helpful in guiding others who may wish to undertake a similar campaign. With the hearty approval of the superintendent of the public school system and of the art supervisor of the schools, a mimeographed announcement was prepared. The contest was opened to pupils of the junior high schools and the seventh and eighth grades of the public schools, and the size of the posters was set at 14 by 22 inches. A list of some forty slogans suggested by the Garden Club was furnished, and the art teachers were asked to guide the children in working out suitable illustrations for these. A period of eight weeks was allowed for the work and a committee of judges was appointed to pass upon the results. One prize of $15 was offered to the seventh and eighth grade school having the best group of 15 posters, and an-

other of like amount to the junior high school having the best group of 20.

The Garden Club Committee saw to it that the local newspapers received weekly notices of the progress of the contest and daily notices after the judging had taken place, and the posters were on exhibition in the public library art gallery and the art rooms of the high school. Illustrations of some of the outstanding posters were then also published and a great many visitors came to see the exhibits. The poster receiving the greatest number of votes for individual excellency showed a tiny tot about to pick a gorgeous red lily, but a gnarled old tree in the background, with irregularities near the base of its trunk forming a grotesque face and two twisted branches simulating arms threateningly outstretched, was saying, "Stop!" The best in the winning grade school collection showed a silhouette of a girl admiring a lovely flower in a meadow, with the legend, "Preserve God's gift—Wild Flowers." The outstanding poster in the prize-winning junior high school set represented a little boy with trowel in hand bending over a group of ladyslipper orchids, but at the base of the sketch were the words "Leave my roots." The contest was formally closed with an evening lecture on wild flowers, illustrated by colored lantern slides, after which the prizes were awarded to children representing the successful schools. But its favorable effects, in arousing in the minds of both the children competing, and the adults reached by the attendant publicity, the idea that our wild flowers need protection, will last for a long time to come.

In addition to the danger of destruction by too extensive picking and uprooting, our wild flowers are constantly subject to the ravages of fire. During the first three weeks of April the newspapers of Philadelphia—in which city this talk is being given—contained reports of nearly four hundred fires in the woods and meadows of nearby parts of Pennsylvania, New Jersey and Maryland. The damage done to the trees, and to structures reached by the flames, amounted to many thousands of dollars; the loss in wild life, while it can not be calculated in money, must have been enormous. All nature-lovers should continually endeavor to arouse public sentiment against setting fires in the woods.

So small, however, is the number of active conservationists, and so large the group of those indifferent or hostile to their ideas, that other methods of saving our rapidly vanishing wild life will also have to be followed. It will be necessary to set aside more wild life preserves, and give them better protection.

During the past few months considerable attention has been directed toward making what is left of the Florida Everglades into a national park. No conservationist who travels far in Florida can fail to be horrified by the utter ruin which has been wreaked on nature in most parts of that state. In the course of a day's drive, one is pretty sure to come upon a dozen areas where forest fires are either actively burning or have recently gone out because there was nothing left to burn. On all sides are seen what were up to a few years ago magnificent hammocks filled with luxuriant tropical vegetation, but are now reduced to groups of pitiful charred stumps. So anything that can be done to save what little natural beauty still remains from complete destruction will be worth while. Personally, however, I am not convinced that it will be desirable to create a national park in the Everglades, because that would mean building an extensive road system there, and the coming in of hordes of tourists, some of whom would be careless with matches; and once a fire is started in the deep humus soil, its extinguishing is a pretty difficult and expensive matter. If any

one doubts that fires can do damage in that region, they should look up Small's recent book, "From Eden to Sahara—Florida's tragedy!" In this there are actual photographs, showing how places looked "before and after." And among the areas partially ruined are included the Royal Palm Hammock, purchased a few years ago by the Women's Clubs of Florida and set aside as a state park, but not adequately protected against fire. So I think it would be better to make the Everglades merely a game-refuge, refrain from draining swamps and building roads, and minimize the danger of further destruction.

Considerable newspaper publicity has recently been given to the possibility of saving what is left of the Okefinokee Swamp in southeastern Georgia, and again there is talk of a national park. A congressional committee recently visited that region to look into the possibilities, and photographs taken on the trip have appeared in the rotogravure sections of various newspapers. There are still considerable areas of virgin long-leaf pine and bald-cypress timber left in that region, although these are rapidly being encroached upon by lumber companies. If the only way to save them is to create a national park there, then by all means let us work toward that end. But it will be well to keep in mind the possibility that this area might instead be made a wild life preserve, where its splendid assemblages of native plants and animals can be made the subject of study by naturalists for many years to come.

The Forest Service of the United States Department of Agriculture has recently announced a policy of setting aside within the national forests distinctive areas that will permanently represent the natural forest conditions of all the major forest regions of the United States. Two types are recognized: "Natural Areas," which are to preserve in unmodified condition areas of a hundred acres or so representative of the virgin growth of each forest or range type to the end that its characteristic plant and animal life and soil conditions—the factors influencing its biological complex—shall continue to be available for purposes of science, research and education. And second, "Primitive Areas," in general larger tracts than the preceding, which will consist of outstanding areas of the wilderness type where natural conditions have not been materially altered; their number and location will be determined by public needs, and road and trail development or other improvements will be kept to the minimum necessary for adequate fire protection and administration. This is a splendid step in the right direction; but we need also large numbers of smaller preserves throughout the country.

Some of our states already have extensive park systems, although by no means all state parks function as places of wild life conservation; most of them are of necessity open too freely to public use for that, and with even the best of intentions on the part of visitors, the tramp of a myriad feet during the season will destroy all but the coarser and weedier of the native plants, and send all but the tamest of wild animals scurrying to other haunts. So in addition to state parks we need state wild life preserves, where public use is carefully regulated, but visits by naturalists and teachers are encouraged.

The water supplies of many communities come from springs and streams in restricted areas which must of necessity be protected from the pollution which would inevitably result were the public freely admitted, and such areas seem to be ideal for wild life preserves. I have personally visited but one locality where advantage has been taken of a place of this sort, the wild flower preserve of the Princess Anne Garden Club, in eastern

Virginia. The city of Norfolk has given that club the privilege of occupying a small section of woodland on the shore of one of the lakes which are used as water-supply reservoirs, and this has been surrounded by a high fence, the gate in which is kept locked, and only specially authorized persons hold keys to it. A start has been made in clearing out weedy plants, and in introducing into the area attractive ones which are native to the general region, and a refuge is thus made available for the native species which are disappearing so fast from that part of the country. The great advantage of taking over such a place is that the organization administering it is under no expense for protection, as the city must necessarily maintain guards to keep its water pure. I heartily urge other garden clubs to consider the possibility of taking over such watersheds for wild flower preserves in their communities, and will be glad to learn of the success attained in individual cases.

Before extensive transplanting of wild flowers into such preserves is undertaken, however, some study must be made of the soils existing there, and the requirements of the individual species concerned. There will be no use trying to grow trailing-arbutus or moccasin-flower, for instance, in a patch of neutral or alkaline soil, as such plants are sure to die in a year or two unless an acid-reacting humus soil is provided in the first place, and permanently maintained in that condition. And it will not do to jump at the conclusion that a soil is acid just because moss is growing on the ground, or lots of dead leaves are strewn around. The only way to be certain that the acidity is high enough is to make tests with indicators, that is, dyes which change these colors with different degrees of acidity and alkalinity.

Some provision must also be made to exclude weeds. I once was invited to look at a wild garden which had been laid out on a large estate, at considerable expense, in which, so I was informed, there had been planted hundreds of attractive and delicate spring flowers. When I reached the spot, I saw there a most luxuriant mass of poison ivy, and only after some search was I able to discern a few miserable hepaticas and trilliums fighting a losing battle to maintain themselves. The owner refused to spend the additional sum which would have been necessary to employ a gardener with enough knowledge to keep down the weeds without injuring the introduced native species, and so succeeded only in preserving some plants which needed no protection whatever. Remember that a wild garden must be weeded quite as much as a cultivated one, and count on employing someone sufficiently acquainted with native plants to be able to tell the weeds from the flowers.

Summarizing what I have said in a few words: Every one who loves our wild flowers should do all they can to prevent the unnecessary destruction which is going on all around us. Education will help, but it must be supplemented by the creation of a sufficient number of wild life preserves, both large and small, national and state parks in the few suitable places, but in addition a larger number of smaller areas throughout all parts of the country. Let us all do everything we can to save at least a little of the present natural beauty of our woods and meadows for the enjoyment of future generations.

A MODERN EDUCATIONAL PLANT

By T. SWANN HARDING
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A DISCREETLY anonymous article, "The Lobby We All Support," in the May, 1931, *Nation's Business* brought me up with a sudden start to realize how utterly out of touch with reality in other lines a specialist in one line can be these days. It is very odd, for instance, to observe how a person who is, viewed from the standpoint of education, an officer in charge of the diffusion of knowledge, can become to the business eye a "publicity" and "propaganda" expert with all the invidious shades of meaning those words have recently acquired. That word propaganda, particularly, carries with it a wartime connotation that makes liberals and conservatives alike shudder and feel their pocketbooks.

Not very long ago, Dr. Nicholas Murray Butler wrote, "The extensive and intensive study of natural science, now carried on over more than a full generation, has made no impression whatever upon the public mind. That mind continues to come to its conclusions and to formulate its choices with serene unconcern as to whether any such thing as scientific method exists." Dr. Butler probably exaggerates, it is true, particularly when we consider the advance of scientific methods used by the farmer of to-day, but his statement is worthy of consideration nevertheless. Any modern institution which uses modern methods and modern machinery in the diffusion of knowledge should at least help meet this deficiency.

Years ago the great sociologist, Lester Ward, declared that less than one out of each hundred discoveries of modern science is really understood, or in fact even known about, by one out of every hundred of the general population. Consequently, he argued that our exact scientific knowledge, which gives a new and abiding sense of value and importance to human life in every sphere—not only agriculturally—is just about one ten thousandth useful. In short, we develop just about one hundredth of one per cent. of the potential social utility of science. This is true to some degree in agriculture, where but recently it was authoritatively stated that a lag of 25 years existed between the knowledge of agricultural science in institutions of learning and in the minds of scientists, and its practical utilization on the farm.

That is somewhat the condition information and extension officials confront in the Department of Agriculture. They confront, in the first place, a vast and constantly increasing body of realistic knowledge which is exact, verifiable, demonstrable and communicable. They confront likewise certain practical applications of scientific principles—the motion picture, advertising and the radio, for instance—which, while perhaps developed for other ulterior purposes, have simply inconceivable potentialities as agencies for the diffusion of knowledge. Finally, they confront the problem of so articulating modern mechanisms for the diffusion of knowledge that the facts ascertained by scientists in the Department of Agriculture may be put to work as quickly as possible.

In doing this they find themselves repeatedly criticized as units in a vast bureaucracy which exists for its own self-perpetuation. An officer charged with the duty of making scientific knowledge available and comprehensible to the public may find himself described as a propaganda fanatic—I speak rather generally than specifically here—ever

eager to get more money from Congress, to create new jobs, to stalk before the public as a noble benefactor, and senselessly to increase the milling output of "publicity" regardless of the demand for this commodity. So far from reality is this mythical portrait that one wonders by just what qualities of the feverish imagination it becomes possible to paint it.

What are the facts? We live in a democracy which has gone on record in favor of free education. This means that the individuals who make up that democracy will in great measure govern the type of education served to them. It even means that they will, in certain instances, demand the creation of certain bureaus even though government officials in Washington might not prefer to see them created at the moment. For it is a matter of record that numbers of government bureaus have come into existence as a direct result of the insistent demands of citizens who saw the wisdom of research or service in those particular fields. It is also a fact that a bureau is far less likely to come into existence because of the yearning ego of a department official than for any other reason. Indeed on a number of occasions the administration's axe functioned to cut off movements intended to grow into new bureaus.

Furthermore, it must not be overlooked that in building up the scientific staff that necessarily mans a large educational institution like the Department of Agriculture, certain men are appointed because they are specialists and are expected to visualize national needs. Thus it is expected that a soil specialist will focus his attention upon the problem of soil erosion and will, in any way he possibly can, arouse a lethargic public to the necessity of protecting our valuable farm lands.

In a general way, while we have the finest school system existing in any country, these schools, as a whole, do not constitute a great structure planned as the Empire State Building or a battleship is planned. They represent rather a growth like a coral island or like some ramshackle country manor house—an empirical development wherein scrapping and rebuilding have gone on simultaneously. Hallowed and almost impregnable traditions have grown up, among them being the inviolability of the classroom, and so modern mechanisms have fought their way slowly to acceptance. A system of planned education, however, would make use of all modern mechanical and social agencies in a closely integrated manner in order to diffuse knowledge as widely and as quickly as possible. The schools, the research laboratories, the libraries, the museums, the motion picture, the radio and the press would be closely articulated into one functioning mechanism for the spread of knowledge.

It so happens that the United States Department of Agriculture is nothing more nor less than a strictly modern educational plant which has efficiently utilized the latest model mechanisms for educational purposes. It must be viewed as an educational institution. To view it through the eyes of competitive business existing in a profit economy is altogether wrong. Note that I do not say business is wrong. Business has to be what it has to be in this age. What startled me in the article in *Nation's Business* was simply that any one would choose to parody an educational institution in terms of business aims and psychology.

The Department of Agriculture maintains scientific laboratories wherein fundamental research is performed. But it does not intend that this new knowledge, actually created by its experts and therefore its most valuable product, shall be sealed away on shelves from the light of day. Even if it wished to do so the department would not dare hoard the knowledge it develops. If it could not

enlist the cooperation of the press and the radio industry in the task of acquainting the public with the results of its activities, other means, which would be far more expensive, would have to be devised.

When a new method is found of eradicating cattle ticks the public is told about it. What possible good could come of spending money to devise means of treating worms in animals, or of conquering contagious abortion or hog cholera or bovine tuberculosis, and then refusing to use any available modern agency to acquaint interested citizens with the fact that this knowledge had been ascertained and was at their disposal? What, indeed, would be the use of hiring a man to work on problems in forestry, to combat plant diseases, or to fight dangerous entomological pests, and then denying him the right of giving wide publicity to the results he has achieved and of seeking to arouse the public to the dangers which inhere in ignoring certain pressing problems?

Hence the Department of Agriculture does not hoard its knowledge. It effects the distribution of its product, if I must use business terms to gain the confidence of business men. It effects this distribution, I venture to say, more efficiently than industry to-day effects the distribution of its products, for every economist will tell you that our system of distribution is not what it should be. The Department of Agriculture accomplishes the distribution of its product, knowledge, by strictly modern means.

It has libraries manned by specialists and ready to serve both those within and outside the department proper. It has, in various bureaus, exhibits which make graphic the findings of the scientists that he who runs may read and learn. It has enlisted the services of the radio and it has done this so effectively that not only do the great commercial broadcasting companies view its programs as an asset so valuable that it is given free time, but public demands expressed in thousands of letters literally compel the department to view educational broadcasting favorably. It has enlisted the services of the motion picture, the educational potentialities of which have seldom been realized. It uses charts and posters extensively. Finally, since it is extremely difficult for the ordinary reporter or free lance writer to interview scientific specialists, and to present the results of those interviews accurately and yet popularly, it maintains a small staff of trained writers who are especially equipped to give the press material it can use already prepared. Aside from this, of course, the department utilizes the printing press itself to the full in the publication of various scientific, technical and popular booklets and periodicals which, again, go out to the public on specific request.

So far as my knowledge extends I believe there is no educational institution in America to-day which utilizes modern means for the diffusion of knowledge so effectively as does the Department of Agriculture. There is no diversity or diffusion of interest here. All—libraries, exhibits, the radio, the motion picture, the newspaper, the printing press—work to one end in closely coordinated fashion. In lieu of public schools the Department of Agriculture maintains, where they are most needed, extension service workers and county agents as local representatives whose business it is to make certain that the department's product, the knowledge of agricultural science, reaches the public, who support its activities, in the best possible manner. The system is complete from laboratory to furrow, and it is as impressively modern in its mechanisms as it is complete. To have such an educational organization described in caricature from the standpoint of business ethics is nothing less than startling.

Most criticisms of the federal infor-

mation services run according to the same formula. First they imply that these services are really "publicity" agencies, in the unfavorable sense of that term. It is then charged or implied that material is put out to advance the interests of bureaus and bureaucrats, rather than the interests of the nation. Legitimate information, scientific and administrative, is supposed to be skilfully adulterated with illegitimate publicity for the benefit of individual government employees or government units. Call a government information service a "publicity agency" and it seems to follow logically that it is up to no good.

Yet is it not proper—is it not socially desirable—to seek publicity for the results of an important scientific project, a quarantine regulation that requires public cooperation, or a plan for bringing about a better adjustment between farm production and market needs? It ought not to be considered objectionable to engage in so-called propaganda for the control of plant or animal pests, the better utilization of land resources, the more efficient use of farm by-products, the protection and conservation of wild life, the use of selected plant seeds or strains of livestock, or the better handling of food products. Only on topics of this sort does the department engage in "propaganda."

By the law creating the department, the organization is required to collect and *diffuse* useful agricultural information. From the beginning, Congress placed informational work in the department on a par with its research work. Only to the extent that knowledge gained in the department is applied in agriculture and industry is the institution justified. In a sense, the total activities of the department must culminate in information. The public supports this department in order that it, in turn, may give its results right back to the people who paid for them and who can benefit by them.

If the department ceased issuing information, agricultural markets would be thrown into chaos, progress in farm technique would be retarded, protection for the public against the adulteration of food and drugs would be far less efficient, production in agriculture and industry would be impeded and made more costly, and efficient cooperation between the department's scientific staff and economic groups having a use for scientific knowledge would be impossible. Hazards in aviation would be increased. Ocean navigation would be made more difficult. Warfare against animal diseases and human diseases would be handicapped. Science itself would lack the stimulus that comes from regular inter-communication among groups of scientific workers. Information is the best known means of getting scientific knowledge put into practice.

To issue information via the press, over the radio, by publications, and by means of motion pictures and exhibits is an efficient and relatively inexpensive method of accomplishing the desired results. One guaranty that the material issued is rightly adapted to its purpose is the fact that it must pass a very rigorous censorship. Press releases have no chance with the average newspaper editor unless they contain important information concisely written. Newspaper editors themselves would be the first to condemn such material if it were purely propagandistic for purposes of promoting bureaucracy. Instead, editors find that the department supplies them with accurate material it is desirable for their readers to have. Radio material must undergo the exacting requirements of radio listeners. Only information that has genuine public interest is acceptable to the press and the radio.

The radio activities of the department

cost less than $35,000 annually. The stations donate their time and it is certain they would not do this unless their listeners were being properly and usefully served. By radio about five million people are reached daily! Press work costs about $50,000 a year and publications cost $950,000. As previously mentioned, this nation is dedicated to a system of free education for farmers. If it be wrong—if it be socially undesirable—to spend slightly more than a million dollars annually to keep farmers and others advised of the most recent triumphs of science, of the daily markets, and so on, then it is equally wrong to provide free education by the Land Grant Colleges. That this philosophy of free education should be changed—and articles like that in *Nation's Business* really so contend—is rather revolutionary doctrine.

The anonymous author of "The Lobby We All Support" is astonished that the Department of Agriculture issues nearly 25,000,000 copies of its publications annually. These publications are not foisted upon persons who do not desire them. Ninety per cent. are actually mailed in response to direct requests. The department receives nearly 300,000 letters a year from interested listeners to its educational radio programs. If public appreciation is any criterion of the value of the department's informational services, the matter is beyond doubt.

It is unfortunate that attacks like those contained in the article, "The Lobby We All Support," should be published in responsible magazines because they are directed essentially not at the government's informational activities, but at the scientific and service functions with which the information work deals. This follows from the impossibility, at any rate in so far as the Department of Agriculture is concerned, of separating its research and service work from its informational work.

If the department's basic activities are justified and if the government is justified in helping American agriculture, all means legitimately employed to give the results of the work to the public are justified likewise. If, in spreading useful knowledge, this department issued only technical monographs, it might escape more easily the darts of the "publicity" critics. Under such circumstances the public would wait years for others to take these monographs, interpret them, and finally diffuse their valuable contributions to practical knowledge. In trying to make this useful material quickly available in a modern manner to every one who can use it, it is inevitable that occasional ridicule should greet it.

The point really at issue is whether the citizen's contributions to his government in the form of taxes should be used for socially beneficial ends or not. An obsolete theory of government held that taxes were well spent provided the general public derived no direct benefit therefrom, and dubbed as "paternalistic" and "un-American" all efforts of the government to perform functional services which, while necessary, are in the very nature of the case immediately unprofitable—the activities of the Weather Bureau are an excellent example. To-day in the Department of Agriculture we have a very modern educational plant thoroughly equipped to discover new knowledge and to diffuse it. Is such a plant socially justifiable? If its research activities are justifiable has it any right to diffuse, by the best means at hand, the knowledge it has discovered? Is it likely that any enlightened person would answer these two questions in the negative?

SCIENTIFIC EMINENCE AND CHURCH MEMBERSHIP

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IT is difficult to treat religion and religious issues in an impersonal, dispassionate manner. Any attempt to discuss present-day creeds upon any basis is likely to be interpreted as a direct result of deep-seated and inescapable prejudices. Comparisons of church activities often prove invidious, because the person making the comparisons is incapable of assuming an objective attitude. The resultant lack of impartiality reveals itself clearly in the numerous present-day discussions of vital issues pertaining to religion. Not only is there the difficulty contingent upon the attitude of the individual who discusses religion; there exists also an almost insurmountable hindrance which is the result of the attitude of persons who hear or read religious material. There is perhaps no type of presentation more subject to misunderstanding and misinterpretation. Nevertheless, it appears imperative that all available data relating to religion and its effect upon conduct be scrutinized frankly and objectively.

In *School and Society*, for September 24, 1927, Professor W. S. Ament presented data regarding the relationship existing between church membership, education and distinction. In this article, Ament reported that, in proportion to number, the somewhat liberal religious sects have supplied many more individuals in "Who's Who" than have the less liberal ones.

> On the basis of these figures a Unitarian has 222.7 times the chances of a Catholic of appearing in "Who's Who" (1) (p. 401).

> . . . the Congregationalists supply 27 scientists to 2 for the Catholics, a proportional advantage of about 108 times in favor of the "independents" as they were once called (1) (p. 402).

Ament's study was actuated in part by a notation of C. C. Little in *Scribner's Magazine* for November, 1926. Little stated that there was need for data showing whether any relationship existed between success in intellectual endeavor and liberality in religious thinking. Ament estimated success in intellectual endeavor by the relatively crude criterion: inclusion in "Who's Who." The study is therefore merely suggestive of the true relationship between success in intellectual work and liberality in thinking.

It is of course well known that a name may be included in "Who's Who" for many reasons. Thus, many names are placed in this volume because of successful political activity, and because of numerous other types of non-intellectual achievement. It is true of course that inclusion in "Who's Who" is sometimes indicative of notable success in tasks really intellectual in nature. In other instances, however, selection is due merely to the fact that the individual in question has been elected, or appointed, to an office that theoretically *should* be occupied by a person of ability; *e.g.*, successful political candidates in the United States often do not appear to possess intelligence of a high order.

Many opportunists, other than politicians, are included in "Who's Who." A random sampling of individuals in these enviable pages is likely to include

therefore a miscellany of the intelligent and the unintelligent. The writers felt that of all in "Who's Who," the outstanding scientists are most likely to represent the intelligent men of America. This delimitation is somewhat arbitrary, and it appears to restrict intelligent activity solely to the endeavor of the scientist. Obviously, intelligence is reflected in numerous types of work other than science. Nevertheless, intelligence (as adaptive behavior) is undoubtedly clearly and unmistakably reflected in the work of the eminent scientist. Therefore, the writers have studied a particular aspect of religious activity among recognized men of science. This paper presents the frequency with which outstanding scientists are associated with various churches.

The data regarding church affiliation were secured from the 1926–1927 edition of "Who's Who in America." In providing biographical data for this volume, the candidates are asked to report "Religious denomination (if any)." The names of the scientists were secured from the 1927 edition of "American Men of Science," the biographical directory edited by Professor Cattell. This volume contains biographical information regarding approximately 13,500 individuals in the United States who have carried on research in the natural and exact sciences. Of these workers, those who have achieved notable success in their particular fields are identified by means of asterisks.

To identify the eminent in science (for the first two editions of "American Men of Science") ten scholarly representatives of each science were asked to arrange the names of the students of that science in order of merit. The average of these ranks was considered by Cattell to be a fairly accurate index of merit, and asterisks were assigned about 10 per cent. of each group of scientists.

The procedure employed for preparing the 1927 edition may best be described by illustration of how the leading psychologists were selected. Each of the 48 psychologists whose names were included in the first two editions was asked to submit the names of 10 other individuals whose work in psychology seemed to warrant their inclusion in the directory. Those who received 2 or more nominations were asked to propose 10 additional names. The 52 who received the largest number of citations were added to the original 48 to form a group of 100. These names were then arranged in alphabetical order and sent to each of the 100 with the request that the names of the 50 individuals who had done the most important work in psychology be indicated. By this means Cattell secured the names of approximately 50 psychologists whose work was considered by their contemporaries to be extremely significant.

The foregoing summary should make it perfectly clear that the scientists having asterisks attached to their research in "American Men of Science" were not selected arbitrarily. It should be evident also that the group includes the most distinguished scientists in the United States.

A count was made of the total number of names in "American Men of Science" having asterisks attached to their names. The total number was 1,423. Of the 1,423 names, 14 per cent. were eliminated because they were not included in the 1926–1927 edition of "Who's Who." Three per cent. also were discarded because of incomplete sketches in "Who's Who," the names of the scientists in question being accompanied by little more than a cross-reference to an earlier edition of "Who's Who." In all, 1,189 reason-

ably complete biographical sketches were found and examined. Of these 1,189 sketches, 303 (25 per cent.) included information regarding church membership, 886 (75 per cent.) did not. It may be inferred either that the 886 scientists, who neglected to state their church membership, belong to no church or that they did not consider the information of sufficient importance to include when they were preparing their biographical sketches. Absent-mindedness and forgetfulness can not be assigned as reasons for this neglect since the questionnaire that is filled out, by all those whose biographical sketches appear in "Who's Who," suggests specifically that "Religious denomination (if any)" be given.

TABLE I

DISTRIBUTION OF CHURCH MEMBERSHIP OF 303 OUTSTANDING SCIENTISTS IN THE 1926–1927 EDITION OF "WHO'S WHO IN AMERICA"

Denomination	Membership number	Percentage distribution
Congregationalist	66	21.78
Presbyterian	61	20.13
Episcopalian	52	17.16
Unitarian	37	12.21
Methodist	31	10.23
Baptist	16	5.28
Protestant (unspecified)	14	4.62
Friends	6	1.98
Disciples	4	1.32
Jewish	4	1.32
Lutheran	4	1.32
Catholic (Roman)	3	.99
Universalist	3	.99
Reformed Dutch	1	.33
Swedenborgian	1	.33
	303	99.99

Table I presents the number and the percentage of the 303 scientists in the various church groups. Table I does not take into account the frequency of church membership of the total adult population of the country. The data are therefore misleading except when they are studied in connection with the data of Table II. Table II gives the frequency of church membership among the entire adult population. If each denomination supplied its proportionate

TABLE II

DISTRIBUTION OF CHURCH MEMBERSHIP IN THE UNITED STATES AS A WHOLE. (DATA COMPILED BY H. K. CARROLL FOR THE *Christian Herald*, 1925, AND TAKEN FROM PAGE 421 OF THE 1927 "WORLD ALMANAC")

Denomination	Membership number	Percentage distribution
Methodist	8,920,190	23.03
Baptist	8,397,914	21.68
Roman Catholic*	8,023,957	20.72
Presbyterian	2,561,986	6.61
Lutheran	2,546,127	6.57
Disciples	1,759,399	4.54
Episcopal	1,164,911	3.01
Congregational	907,583	2.34
Jewish**	714,270	1.84
Dutch Reformed***	127,000	.33
Friends	115,528	.30
Universalist	59,650	.15
Unitarian	58,024	.15
Swedenborgian***	6,363	.02
Other denominations (Est.)	3,367,385	8.69
	38,730,287	99.98

* The Roman Catholic membership of 16,047,914, representing all baptized communicants, and hence approximately the total Catholic population, has been divided by two to place it on about the same basis as the largely adult membership of the Protestant bodies.

** The Jewish total 357,135, representing heads of families, is multiplied by two for a similar reason.

*** Membership totals for the Dutch Reformed and for the Swedenborgian denominations were obtained from the "New International Encyclopaedia," and are estimates of membership in 1915, the latest year for which the writer was able to obtain data.

share of outstanding scientists, the percentage distributions for the denominations in Tables I and II would be parallel and orderly; the church having the largest total membership would supply the largest number of research workers; the denomination having the next largest total membership would furnish the next largest number of research aces, etc. This situation, however, was not found. Some denominations provide a much smaller number of outstanding research workers than one would predict from membership data, and others furnish many more than their expected quotas.

An overview of this situation may best be obtained by inspection of Table III which reveals the extent to which

TABLE III

NUMBER OF TIMES EACH DENOMINATION REACHES, FALLS BELOW, OR EXCEEDS THE QUOTA (EXPECTED FROM CHURCH MEMBERSHIP DATA) AMONG STARRED NAMES IN "AMERICAN MEN OF SCIENCE"

Denomination	Proportional representation
Unitarian	81.400
Swedenborgian (1 member only)	16.500
Congregationalist	9.308
Friends	6.600
Universalist	6.600
Episcopalian	5.701
Presbyterian	3.045
Dutch Reformed (1 member only)	1.000
Jewish	.717
Methodist	.444
Disciples	.291
Baptist	.244
Lutheran	.201
Roman Catholic	.048

each church group reaches or exceeds its statistical expectation in furnishing research workers. Table III sets forth the proportionate number of eminent scientists furnished by 14 religious denominations. The procedure employed in making Table III follows. In Table I one finds that the Congregationalists supplied 21.78 per cent. of the 303 scientists. Table II shows, however, that the Congregationalists comprise only 2.34 per cent. of the church members of the United States. This means, as shown in Table III, that the Congregationalists supplied 9.30 times as many of the scientists listed in Table I as one would have anticipated from the church membership data. The Unitarians provide 81.400 times their expected quota, the Friends, 6.600, the Episcopalians, 5.701, and the Presbyterian, 2.995 times their quotas. Comment regarding the Swedenborgians and the Universalists is withheld because of the small numbers of cases. All groups, other than those mentioned (and the Dutch Reformed), fall below (some of them conspicuously below) their expected quotas. Table III shows clearly that the Roman Catholics provide the smallest number of research workers in proportion to their number.

Ament reports (for what is undoubtedly a less highly selected group of scientists) that the Congregationalists supply 27 scientists to 2 among the Catholics, a proportion on the basis of membership of about 108 to 1 favoring the Congregationalists. The data in this paper show a proportional advantage in favor of the Congregationalists of 193 to 1! Apparently the proportional advantage in favor of the Congregationalists increases markedly as the group of scientists investigated becomes more highly selected. It is true that Ament's study included data for the several branches of the Catholic church whereas this study treats of Roman Catholics only. This difference, however, does not affect appreciably the foregoing comparison since the Roman Catholic Church includes most of the Catholics of the United States. If this study had presented data for the several branches of the Catholic Church (like Ament's study) the proportional ad-

vantages in favor of the Unitarians and the Congregationalists would have been even larger. This is because the three Catholic research aces listed in Table I are all members of the Roman Catholic Church. The other branches of the Catholic Church supplied no research aces.

A comparison of the two extremes in Table III, the Unitarians and the Roman Catholics, reveals striking differences. The Unitarian appears to have 1,695 chances of becoming very distinguished in science to the Roman Catholic's one!

The objection may be advanced by some readers that, since only about one fourth of the outstanding scientists mention their church affiliation, the data are inaccurate for the several groups that contain few eminent research men. In the judgment of the writers there is no justification for this criticism. There is no reason to assume that members of one church group would be decidedly more reluctant to state their church affiliation than would others. Indeed, it seems logical that the less liberal groups would feel obligated to state their church affiliation *somewhat* more frequently than would the more liberal ones. One inescapable conclusion may be drawn from these data. The more liberal denominations provide many more eminent research men than do the less liberal ones. These data corroborate Ament's results from studying "Who's Who."

The writers have commented previously that the non-liberal denominations do not furnish many research workers. By "liberal," the writers imply relative freedom in interpreting biblical pronouncements and flexibility in reacting to questions such as fundamentalism, the Virgin Birth, etc. The Unitarians and the Congregationalists are generally alleged to interpret such matters with relative individual freedom. Many wings of the Methodist and Baptist denominations tend to be uncompromising in their interpretations.

Special comment should be made regarding the Roman Catholics who supply, in proportion to their number, the smallest number of research workers. As employed in this discussion "Roman Catholic" refers to a single religious organization which, in 1927, had a total membership of 16,047,914 in the United States.[1] When this figure is divided by two, it may be compared with the Protestant denomination figures; this division is necessary because the Catholic Church includes many more children than do the Protestant denominations. The comparisons made in this paper followed this liberal allowance. Striking indeed is the fact that three only of the 1,189 eminent scientists report that they belong to the Catholic Church.

Summary and Comment

1. Only about 25 per cent. of the outstanding scientists in America report church affiliation in their biographical sketches in "Who's Who." About 50 per cent. of all individuals whose names appear in "Who's Who" provide this information. Scientists appear in general to attach little importance to this item.

2. The 25 per cent. who give information regarding church affiliation are associated in most instances with the relatively liberal denominations. The Unitarians and the Congregationalists provide strikingly higher percentages of research workers than do the Catholics, the Lutherans and the Baptists.

3. Noticeable indeed is the small frequency of Roman Catholics among the starred names in "American Men of Science." Among 1,189 outstanding scientists, three only report membership in the Catholic Church.

[1] Data taken from the "World Almanac" for 1927, p. 421.

4. The conspicuous dearth of scientists among the Catholics suggests that the tenets of that church are not consonant with scientific endeavor. It is true, of course, that strict adherence to many Protestant credos would preclude acceptance of certain principles essential in many types of scientific work. The Protestant is generally acknowledged, however, to be less strict than is the Catholic in adhering to ecclesiastical pronouncement. And certain Protestant churches have so enhanced their concepts that it is possible to be fairly liberal in one's thought and still retain membership in church. Thus, it appears that membership in the Congregational and the Unitarian churches is somewhat consonant with scientific enterprise. Noticeable indeed is the close relationship between the liberality of the church and the number of scientists which it shelters. Nevertheless, it is important to note also that about 75 per cent. of the outstanding scientists do not claim affiliation with any church. It is possible that this finding is due in part to the fact that science is a very jealous mistress. Possibly the outstanding scientist is an individual who so busies himself with his studies that he neglects not only church activities but also fraternal, philanthropic, political and social enterprises. The foregoing hypothesis may account in part for the fact that relatively few eminent scientists report church membership, but obviously this hypothesis can not account for the denominational differences that are here set forth.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

WHAT THE ATOM LOOKS LIKE

By Dr. ARTHUR H. COMPTON

PROFESSOR OF PHYSICS, UNIVERSITY OF CHICAGO

To those of us who work in physical and chemical laboratories atoms become familiar acquaintances. I gave as my subject for this afternoon "What the Atom Looks Like," because I wanted to introduce you to these little friends of ours. First let me show you something that an atom can do. I have here in front of me a little electroscope, connected through an amplifier to a loud speaker. My watch has a luminous dial, which has in it a weak preparation of radium. I shall take off the crystal from the face and hold the watch close to the electroscope. Do you hear the "plops" coming from the loud speaker? Remove my watch and the "plops" cease. Repeating the experiment, I find that the face of my watch must be within about two inches of the electroscope before more sounds are heard. What causes the sounds? Evidently something shot from the radium in the watch face. But what are these somethings? Let us call them "alpha particles" for want of a better name.

Lord Rutherford once caught a lot of these alpha particles to see what they made when there were enough of them. He compressed some radioactive gas into a glass tube with walls so thin that the alpha particles would pass right through. After a few days he noticed gas collecting in the space surrounding this tube. On passing an electric discharge through this accumulated gas, and looking at it through a spectroscope, he saw the brilliant colors characteristic of the gas helium. Thus he showed that the things that make these plops, when a speck of radium is brought close to the electroscope, are bits of helium shot from the radium.

Many of you know the romance of helium. Observed many years ago by Lockyer in the spectrum of the sun, it remained unknown on the earth for a generation until Rayleigh and Ramsay, making a precise measurement of the density of the nitrogen in the air, found it different from the nitrogen prepared in the laboratory. Search for the cause of the discrepancy revealed a whole series of new gases—argon with which our incandescent lamps are filled, neon with which we advertise our wares in blazing red, helium with which we now fill our dirigibles, and two others, krypton and xenon, which are now of great value in certain laboratory experiments. Thus was helium found, and now we hear it being formed—the birth of helium atoms. For these alpha particles are none other than atoms of helium gas.

Imagine that by means of such an electroscope as this we have thus counted all the atoms of helium that came through the walls of Rutherford's glass tube, and made the gas that he observed in his spectroscope. How many atoms would we have? In a small thimble filled with helium at atmospheric pressure, the number of atoms is about 1 with nineteen ciphers after it. Perhaps that doesn't mean much to you. Let me put it this way. Two thousand years ago Julius Caesar gave a dying gasp, "Et tu, Brute?" In the intervening millenniums the molecules of air

that he breathed out with that cry have been blown around the world in ocean storms, washed with rains, warmed by the sunshine, and dispersed to the ends of the earth. Of course only a very small fraction of these molecules are now in this room; but at your next breath each of you will probably inhale half a dozen or so of the molecules of Caesar's last breath.

Molecules and atoms are very tiny things; but there are so many of them that they make up the world in which we live. I wish there were time to tell you about the remarkable experiments that have shown the parts of atoms. There are some hundreds of different kinds of atoms, which make up this wonderful world of ours; but all these atoms are made of two more fundamental elements, known as protons and electrons. Hydrogen, the simplest atom of all, has one proton and four electrons. The proton and two of the electrons are concentrated in a tiny nucleus at the center of the atom, and the other two electrons buzz around the nucleus, forming a kind of atmosphere. And so on for the heavier atoms, until we get to uranium, the heaviest of all, which has 92 electrons in its atmosphere.

How the Atom is Built

Old Ptolemy, the ancient Greek astronomer, knew that there was a sun and a moon, the earth and the planets; but he didn't know what the solar system is. When Copernicus and Galileo showed, however, that there is a sun, around which revolve planets in definite orbits, then men felt that they had become acquainted with their world. So, though we have found the parts of which the atom is made, we really don't know the atom until we know how these parts are put together.

Perhaps the best way to find out how something is made is to look at it. If it is like a watch, which we can hold in our hands, this is comparatively easy. If it is the cell structure of a muscle that we wish to examine, we put it under a microscope. But some things are too small to see even in a microscope. By using ultra-violet light of wave-length shorter than ordinary light, we can photograph such things as typhoid bacilli with increased sharpness. But atoms are too small even for this. Now x-rays have a wave-length only a ten thousandth that of light, and if we could use them in a microscope it should be possible for us to observe even the tiny atoms. Unfortunately, we can not make lenses that will refract x-rays, and even if we could our eyes are not sensitive to x-rays. So it would seem that we shall never be able to see an atom directly. It is, nevertheless, possible in the laboratory to get by more roundabout methods precisely the same information about an atom that we should if we could look at it with an x-ray microscope. I have spent a large part of the last sixteen years trying to find what the atom looks like, and it has become something of a game with me.

Last summer, while spending a brief vacation in northern Michigan, I noticed a diffuse ring, not very large, around the moon. Half an hour later the ring was perceptibly smaller, and within an hour we came in out of the rain. This ring was due to the diffraction of the moonlight by tiny water droplets that were beginning to form a cloud. The size of the ring depends upon the size of the water drops—if the drops are small, the ring is big, and *vice versa*. So when the ring grew smaller, it meant that the drops were growing larger. Soon they would fall as rain.

Our method of studying atoms is very similar to this method of finding the size of the droplets in a cloud. Instead of the moon we use an x-ray tube, and in place of the cloud of water droplets we use the atoms in air or helium. For the wave-length of the x-rays bears about the same ratio to the size of a

helium atom that a light wave bears to a droplet of water in a fog. The helium atoms spread the x-rays into a halo in just the same way that the water droplets diffract the moonlight. Likewise now, from the diameter of this halo, we can estimate the size of the helium atom. We can in fact tell almost as much about its appearance as if the atom were under an x-ray microscope. When looked at by such an x-ray microscope the atom looks like a fuzzy ball. If this ball is to appear the size of a baseball, we shall, however, have to use such a magnification that a marble would appear as big as the earth.

In the middle of this fuzzy ball somewhere is the nucleus of the helium atom, which has in it the protons. This cloud-like atmosphere is due to the electrons. We commented a few minutes ago that the atmosphere of the helium atom has only two electrons in it. You may wonder how with only two electrons the atom can seem so diffuse. Did you ever see the boys on the Fourth of July waving the sparklers to make circles or figure eights? Of course the sparklers weren't in the form of circles; they appeared that way because they moved so fast. So here, the electrons give this continuous, diffuse appearance to the atom because they are now here and now there, and we have caught a "time-exposure" of their average positions. This is of course what we would see if we could really look at the atom.

There have been fifty-seven varieties of atomic theories proposed. Lord Kelvin thought the atom was something like a smoke ring; J. J. Thomson said it was a sphere of jelly. Rutherford called it a miniature solar system, while Bohr and Sommerfeld calculated precisely the orbits of the planetary electrons revolving about the central nucleus. Lewis and Langmuir objected, and said the atom is a cube. Not, so, it's a tetrahedron, claimed Landé. "Quite a mistake, it's a diffuse atmosphere of electricity around a central core," says Schroedinger. "Only it isn't diffuse electricity," complains Heisenberg, "It's electrons moving now here, now there, which make up this atmosphere." Thus the debate was waged. Now that we see how it looks we find that they were all wrong except Heisenberg. He seems at last to have predicted correctly what we should find.

THE DISTANCES OF OUR NEARER STARS

By Dr. JOHN A. MILLER

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FINDING the size of the universe is one of the most intriguing problems of physical science. Interest in it became particularly acute in the sixteenth century. Copernicus had presented his system of the world. He had asserted, contrary to the tenets of the church and teachings of all philosophy, that the earth revolved around the sun. Granting his thesis, it followed that we should be able to observe the parallax of stars, from which we could find their distance from us. The great Danish astronomer, Tycho Brahe, lived in the last half of the sixteenth century. Though armed with instruments of then unequaled accuracy, which he used with then unequaled skill, he failed to find the distance from us of any body outside the solar system, and on this basis repudiated the theory of Copernicus.

Following Tycho Brahe, generation after generation of men attacked the problem. By-products of their researches richly repaid this expenditure of effort. But nearly three hundred years passed before a single parallax was found. In December, 1838, Bessel,

a German astronomer, announced that he had found the parallax of 61 Cygni, a star in the constellation of the Swan, and in January, 1839, Henderson, of Edinburgh, announced that he had found the distance of Alpha Centauri, a bright star in the southern heavens. It turned out that this star is nearer us than any other star whose distance we have found.

The theory underlying the determination of the distances of the nearer stars is simple. It is that of triangulation; it employs the same principle that a surveyor uses to find the distance from his instrument to a point which he can not reach but can see. The astronomical problem is this. On some date, say June 1, the observer draws a line joining the earth and the star, measures the angle between that line and a line joining the earth and the sun. Then on December 1, six months later, when the earth is 186,000,000 miles from the first position, he repeats this process. He then has three parts of his triangle, the two angles he has measured and the distance 186,000,000 miles. From these data he can compute all other angles and sides. He is chiefly interested in the angle at the star, one half the value of which is called the "parallax" of the star. After this has been computed the distance of the star from the sun may be found. This method of determining stellar distances is called the trigonometric method, because it employs the principles of trigonometry. It is a fundamental method, for most other distance determinations rest directly on results obtained in this way. Pursuing the same method, astronomers from 1840 until 1910 determined the distances of 360 stars.

In practice the method is less simple than the description leads one to believe. All the stars are so far away that the triangle we draw is a very slender one. The angle at the star is very small and the farther away the star is, the smaller the angle. How small this angle is, one may realize if he draws two lines from the center of his watch dial to eleven and twelve o'clock, respectively. The angle between these lines is 30 degrees. The largest angle at the star that has ever been found is 1.5 seconds, or about one seventy-five thousandth of 30 degrees. So a very slight error in the measures may become a considerable part of the quantity we are seeking. Therefore the question—How reliable are these determinations of distances?—is frequently asked not only by the layman, but most anxiously by the observers themselves.

The unit of stellar distance most commonly used is called a light year. Every one will recall that light travels with a velocity of 186,000 miles per second. A light year is the number of miles that light travels in a year which is approximately six million million miles—six followed by twelve ciphers. Alpha Centauri, our nearest star, is 4.3 light years distance, or 4.3 times six million million miles. In 1910 Kapteyn, the great Dutch astronomer, assembled and published a list of 360 stars, for which he believed reliable distances had been determined. It was the net result of the labor of parallax observers for seventy years.

New types of inquiry as to stellar properties and behavior, such as their motions, their brightness, mass, density and other things, had evolved many formulae, many of which contained the distance of the star as a variable or parameter. This made it perfectly clear that astronomical progress demanded a substantial addition to Kapteyn's table. Moreover, it was evident that this increment should include stars of various properties, such as spectral type, motions, etc., and that, if possible, the quality of our knowledge should be improved. Experience had shown that distances found by use of the photographic plate were of a higher degree of precision than those found by the older method.

Led by Dr. Frank Schlesinger, then of Yerkes Observatory, American astronomers inaugurated an intensive parallax campaign. Seven observatories in the United States participated and are now participating in this campaign. The work was for several years under the direction of a committee of the American Astronomical Society. By inter-agreement certain lists of stars were observed by all the participating observatories in order to weed out "systematic" errors. Certain other lists were observed by two or three observers. The intercomparisons led to greater refinement, and it is not too much to say that the exactness of our knowledge of stellar distances has been enhanced more than 100 per cent. in a quarter of a century. Certain European observatories have carried parallax programs also, notably the Royal Observatory at Greenwich, which has confined its efforts to the north polar regions.

We know now the distance of four thousand stars with a reasonable degree of accuracy. The trigonometric method is limited (because of the slender triangle) to distances not exceeding three hundred light years. I believe that most astronomers would agree that for stars not more distant than two hundred light years, the trigonometric method is more exact than any other yet devised. But stars situated at a distance of two hundred light years or less form a pitifully small fraction of all those visible in our telescopes.

Knowing the distances of stars enables us to replace conjecture by fact in many lines of inquiry. To illustrate, I shall cite three examples. Men measure the apparent brightness of a star, that is, its brightness as it appears to us. But the apparent brightness of a luminous object depends not only on the actual brightness but also on the distance of the object from us. In fact, the apparent brightness varies inversely as the square of its distance from us. If we could move twice as far from the sun as we now are, it would appear only one fourth as bright. Now we have measured the apparent brightness of many thousand stars, and for those whose distance we know, we can and have computed their actual brightness. The effect has been to make us realize how puny our imaginations have been. We have found beyond peradventure that our sun is hardly an average star, that compared with it there are giant suns, many of them giving thousands of times as much light as it does. Others radiate only a small fraction of that of the sun. The well-known star Canopus in the southern sky is 80,000 times as bright as the sun.

We are curious to know the mass of stars, *i.e.*, how much they weigh. We can answer this very exactly for double stars if we know how far their components appear to be separated, the time they require to revolve around each other, and the distance they are from us. There are 16,000 pairs of double stars known and as years go by each will give up all the data necessary to compute its mass. Then we can tell also for these stars how their actual brightness is related to their masses.

Pease at Mount Wilson Observatory in 1920, using an interferometer invented by Michelson, measured the apparent diameter of the great orange-colored star in the constellation of Orion. It was an astronomic event of transcendent importance. The distance of the star from us had previously been found. It was now easy to compute its diameter in miles. It turned out to be 215,000,000 miles, or 30,000,000 miles greater than the diameter of the earth's orbit. Antares, the bright red star in the summer constellation Scorpio, has a diameter of 400,000,000 miles, while Arcturus is slightly smaller.

There are other methods for obtaining star distances. Using the data collected by the trigonometric parallaxes astronomers have been able to translate into distance certain characteristics of the

spectrum of a star. One of these, known as the spectroscopic method, uses the principle that the relative brightness of certain lines of the spectrum varies with the distance of a star from us. By correlating these phenomena for stars whose distance is known with like phenomena in the spectrum of a star whose distance is unknown, Adams and his colleagues have been able to determine star distances. The labor involved is very much less than that of obtaining trigonometric parallaxes and for very distant stars more accurate.

In 1924, Schlesinger published a catalogue giving the distances of all stars whose distances we knew with reasonable accuracy. These distances, in the main, had been determined by the trigonometric method. 1,870 stars were listed. Of these six hundred were nearer than one hundred light years. It is hardly necessary to repeat that we have spoken only of the nearer stars, our next-door neighbors. Most stars are farther from us than that. By indirect methods men have shown quite conclusively that many stars in our local universe are thousands of light years distant and that other universes of stars which we can photograph are thousands of millions of light years away.

MAN'S CONTROL OF HIS OWN DEVELOPMENT

By Dr. OSCAR RIDDLE

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Talking with bees will be a tough job, but easier than a voyage to another planet.—*J. B. S. Haldane.*

FEW people have given thought to the possibilities of a real and voluntary control of man's own physical and mental development. Yet the surprising facts which forecast such control would warrant several superlative things. They seem worthy of the skill of a whole city of scientists and of the best efforts of the poets as well. Certainly the outlook in this direction deserves the awakened thoughts of all who love life, since the dignity of life and man becomes greater and sounder once it is proved that man has begun to use his creative power upon his own personality and destiny.

All civilized people now think of it as natural enough that man already has a large measure of control over his own diseases. But the control of such things as stature, color, sex, immunity from disease and temperament are usually not brought by the public into the same picture. The experimental biologist, however, can now place these two sorts of control into essentially the same frame; he can show that there is a fairly close connection between those basic facts which already serve us in the control of disease and those which promise an eventual control of our physical development. Many of the big things concerning disease were learned from the study of lower forms of life—from bacteria to guinea-pig and monkey. These things have been rather easily and rapidly applied to man. Practically all that we know of the control of growth and development has been obtained from the eggs, embryos and young of simpler forms of plant and animal life. Though it is sure that the application of these results to the human will be a long and very tough job, it has become clear that only practical, not natural or theoretical, difficulties have to be overcome; and clear also that many of those difficulties must sooner or later dissolve under the pressure of searching scientific effort.

The control of development of animals and human beings can be approached from two very different sides. The reason we have these two wholly different sets of tools for controlling development is that two wholly different kinds of things are everywhere and necessarily concerned in growth and development. One of these necessary things is a large number of so-called hereditary factors or genes. These genes are substances, doubtless very definite chemical molecules, which are passed on from parent to offspring. Any change which we might make in these hereditary factors would have the great merit of remaining in their changed condition during following generations. In other words, this sort of change—made in a few individuals—could automatically appear later in the thousands of descendants of these few individuals. But the genes are extremely small and the human egg very inaccessible; there is here little hope of our ever being able to pluck out undesirable genes or to invent and insert new ones. The other method of approach is wholly different. It requires no change in the hereditary factors carried by any one. It undertakes to modify or control one or another characteristic through the discovery and control of what is usually called the environment—though, unfortunately, no one has as yet been able to imagine the extreme complexity of that more important part of the environment which is in closest contact with the genes. This method of control would be applied, at least during youth, very much as is medicine and education, to each individual and to each generation.

Though I am certain that the use of the first method, that of controlling the hereditary factors, has an extraordinary value in obtaining the fittest and best agricultural varieties of plants and the most useful types of domestic animals, I am forced to conclude, however reluctantly, that in the case of the human family the control of special environmental factors is by far the more practicable and more useful method; and further, that it is the only method which can extend help and power to all human beings. Let us now mention a few of the notable triumphs of the experimental biologist which lead to this conclusion and which should make it clear to all that this second method of the control of development is of extreme value and consequence to man; this value and effect being parallel to the beneficent effects of the wise and careful cultivation of an agricultural plant.

In one word the laboratories have shown that when we have access to living animal matter that is working very hard and successfully at the job of development—that is, when we examine it in egg, embryo and early life—we find it highly plastic and controllable. Development begins with the egg and the egg develops by dividing itself into two, four and then into thousands of cells all of which unite in the production of a single embryo; but in many cases the experimenter has found that if he, or something else, separates these two or four cells they will each form a separate embryo or animal—two or four animals instead of one. You know also that the egg-cell of most animals or plants develops no embryo at all unless another cell—a pollen grain or sperm cell—unites with it. Experiments on many such eggs have shown, nevertheless, that they can be persuaded to develop in the complete absence of any such male cell. The withdrawal of a little water from the egg, or a little shaking of the egg or still another kind of disturbance, will often cause it to proceed with the whole business of development. Even fatherless frogs have been thus produced. In some simple worm-like animals which can survive being cut into two or more pieces it has been found that, under certain conditions, those cells and tissues

which would normally form the tail can be made to reverse their destiny and form a head.

Again, the eye of the frog develops quite like that of the human, and the young tadpole—just like ourselves—uses a bit of his skin for the building of the crystalline lens which lies in the center of his eye. But the experimenter has proved that skin from the back or tail of the tadpole, if transferred to the eye region before the eye is formed, will make just as good an organ of vision as the skin normally used for this purpose.

The color of the skin or hair, at least in some animals, is another thing which may be modified if we very carefully see to it that rather special conditions attend the skin and hair during their growth. One experimenter shaved some of the white hair from the backs of white Russian rabbits, and then kept this bare skin cold while it grew the new hair. These cooled areas of white skin turned black and the hair that grew from them was black hair, not white. This particular and simple method will not bring about a similar color change in all races of rabbits; the kind of genes carried by the race also helps to determine the result. Another experimenter could so graduate a dosage of x-rays on the skin of black mice as to produce white hair, not black.

A certain race of flies bred in a laboratory here in New York were found to have the odd property of developing extra legs—some of them in inconvenient places. It was later discovered that if the eggs and early growth-stages were kept quite warm these would develop into entirely normal flies. Evidently the climate suitable to these flies is the tropics, not New York. Here we see that a special bit of the external environment is sometimes able to correct or to counteract the usual influence of a harmful gene.

It is now known that the sex of many animals is subject to control and reversal. In the oyster the experimenter does not even have to direct this procedure, since it appears that something connected with season readily accomplishes a change in sex. One and the same oyster may be a female this year, a male next year; or perhaps a female in the summer and a male in the autumn. Also in much higher animals, such as birds and frogs, the development of sex has been experimentally changed or reversed. These cases of sex change are of high importance because they have brought with them a new insight into the nature of sex difference, and because they sharply illustrate the control which man has already exercised, in certain favorable instances, over a characteristic which is present in nearly all living things.

It is a great mistake to assume that the qualities possessed by living things are their optimum or best qualities. Two or three instances from animals will show that usual body size is in fact merely stunted growth. It has been shown that the usual growth-rate and size of mice is only half that attained when the young mouse continually gets all the milk it wants. Rats given their full needs of vitamines grow to double the usual size. One type of our white blood cells becomes at least ten times larger when properly fed. The growth of some single-celled organisms can be greatly increased simply by letting some rays of radium play around them. Focusing our view closely upon events and conditions within a little clump of living matter when it is developing most actively—when each hour or minute presents us a different and more advanced animal struggling with the whole of the natural world—we can learn that nature is neither wholly dependable nor beneficent; a controller of environments here faces a wide universe of conditions which may be controlled to

the advantage of the organism. Man can not be excluded from the dramatic implications of this statement.

In the plant world, also, development is under similar control. It has been shown that a growing soy-bean can be made to form either of two essentially different mature plants, depending upon the particular rays of light which are permitted to attend its growth. Grown in red-yellow light it becomes a twiner and you regard it as a delicate vine; grown in blue-violet light it is a sturdy shrub. Structure, form, sex, size, color and capability are all things which can be changed in extreme degree through the discovery and use of one or another factor of the internal or external environment.

Our final illustrations of developmental control relate to the very specific substances called hormones. More than a dozen of these powerful products are known to be secreted by the several small glands present in our bodies and in those of all higher animals. Already those little human dwarfs known as cretins are having inches added to their ultimate height, and additional power to their brains, by the use of the hormone prepared from the thyroid gland of the ox or sheep. Another such gland which has a very peculiar importance in the control of our development lies at the base of the brain and is called the pituitary body. One of its secretions, known as the growth hormone, largely decides how tall we are. Much of it means that we become tall; less of it means that we are not so tall. This growth hormone can be taken from ox, sheep or pig and injected into other animals; already used in this way on salamanders, rats and bulldogs it caused these animals to grow to double their normal size. Within a few years this hormone will undoubtedly be purified and then used to increase growth and stature in human beings. And here I hasten to add, in sheer self-defense, that you should not write to me about the possibilities of your lengthening your legs and spine. An earlier experience with a press report suggests to me—perhaps erroneously—that about a third of the human race will be interested in the personal use of this substance. This hormone does not yet exist in a form suitable for human use; just as soon as it is so prepared your physician will know all about it, and he, not I, must guide you—if still young—in your effort to add a cubit or two to your stature.

These few remarks have indicated that the developing individual can be modified by changing either the hereditary factors or the specific conditions under which development is permitted to occur. In the case of man we find our control largely, though by no means solely, limited to a control of an extremely complex environment. In a far deeper sense than now the man of the future must, therefore, become a "maker of environments" in order to control his own structure and capacities to the extent that he has already controlled these same things in plants and in other animals. On some future day all men may have daily before their eyes a few living human examples of man's power to control parts of his own development and destiny; the deeper significance of those examples will then be inescapable and this will bring a lot of mental freedom. That result may be the best of all.

THE LOCOMOTION OF THE SLUG

By Dr. H. A. ALLARD
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THERE are many ways of putting the body in contact with the ground, to accomplish locomotion. Not least interesting among these is the mode of locomotion of slugs. The particular slug which the present discussion deals with is the great slug (*Limax maximus* Linnée).

These slugs introduced from the old world are very numerous in damp, shady localities in the vicinity of man where there is an abundance of vegetation and leaf mould. At night they appear on the walks and leave their queer, persistent footprints as long meandering trails of more or less uniformly spaced viscid spots. When seen in the sunlight at the right angle, these spots reflect the light like thin mica. Fig. 1 shows a photograph of a concrete walk at dawn after these creatures have spent the preceding night trailing over its surface.

It has always been something of a puzzle to me as to how the slugs made these trails as they moved along seemingly so steadily and smoothly, when casually observed. I decided finally to look into the matter and will report my findings.

Since the footprints are circumscribed viscid spots, it is evident that there must be definite points of contact between the body and the walk. This is easily demonstrated by placing the eye close to the walk on one side of the creature and holding a flashlight near it on the other side. Dark shadows demonstrate contact points, with interspaces where the light passes beneath the slug's body.

In order to study some features of its locomotion marks were made on the walk where the contact points were placed beneath the body of the slug, beginning with the first or foremost one at its anterior end.

As the creature moved along, it was noted that the tail in every instance made the last point of contact at each marked point, and here a viscid spot was always left behind as the slug progressed in its locomotion. In each instance the free tip of the posterior between the spots seems gradually shortened until it was brought upon the last spot. At the forward edge of this viscid spot the posterior or tail portion of the body was again made free as far as the hindermost point of contact toward which it was moving.

It is evident that every part of the under surface of the body, from head to tail, serves as a sole or foot, and each point of contact is a footstep, so to speak, upon which the body rests as it moves along. As the anterior portion of the body is advanced beyond the first contact point, the neck is once more lowered and a new point of contact made over which the superstructure of the body proper seems to flow along with such perfect smoothness of progression as to excite wonderment in the observer.

It would appear that the entire under surface of the slug is a big, thick muscular foot or base upon which the body itself seems to be mounted. If a bit of débris to be used as a marker is placed upon the slug's body near the anterior end and at any point from the mid-dorsal line to the edge of the whitish foot, it will be seen that this merely moves along maintaining the same relationship level with respect to the viscid spots beneath, laid down upon the walk. In other words, this demonstrates that we are merely dealing with the body superstructure somehow gliding along in toto, and have not yet seen the true axis and mechanism of its locomotion, which appears to be quite hidden from view beneath the creature's body.

A piece of clear window glass was now interposed in its path, upon which the creature at once climbed. I now removed it to a strong light, and with a hand magnifying glass found it an easy matter to study the creature from all sides. It was not in the least disturbed but moved freely over the smooth glass giving me every opportunity to observe it in the greatest detail. A most interesting feature is revealed. On the smooth glass, the creature appeared to keep its entire foot in close contact with the surface, so that only an unbroken trail of viscid smear was laid down. As it crawled over the glass, the white expanded foot was almost as wide as the body. Along the middle of this was a narrow clearly outlined band extending the length of the slug and comprising about one third of the entire width of the foot. As a creature moved its outstretched body along, a series of light and dark waves passed rapidly, from the tip of the tail to the anterior end, these coming and going in a steady progression toward the head so long as the slug moved. It was at once evident that here lay the secret of the slug's locomotion. So far as I could determine with a small magnifying glass, this narrow central longitudinal axis, the locomotive band, is thrown into a succession of many waves, over which the body superstructure moves along as smoothly as if it were on rollers. As a matter of fact the mode of locomotion seems to be of this order, or perchance can be likened to that of the caterpillar tractor, except that in the case of the slug there is no return of the tread.

A more detailed study was made of the frequency of these waves concerned with the progression of the slug. A space of one inch was marked on a piece of white paper. The hindermost edge of this one inch space was brought even with the tip of the slug's tail, and as the creature moved forward in a direct course, a count was made of the waves passing a point placed a short distance in advance of the front line delimiting the inch space. When the tip of the tail had advanced just to the forward line setting off the inch, the count ceased. Many counts were made in this manner, with the slug moving at various speeds. Twenty-six different counts gave a mean value of 27.4 waves required to allow a progression of one inch distance. This number was closely approximated in nearly all counts as the following data shows:

	23 waves	: 2	instances
	26 "	: 5	"
	27 "	: 3	"
	28 "	: 9	"
	29 "	: 5	"
	30 "	: 2	"
Total	714	26	

Mean 27.4 waves.

Since the space traveled is one inch, and 27.4 waves were required to advance the body this distance, we have a forward displacement of the body of .036 inch for each wave.

The speed of a slug is scarcely worthy of emulation by a human, yet speed is merely a relative matter and even the slug has its averages and maximums.

Using a stop watch, counts were made of the time required in traversing a distance of one inch on a clear piece of window glass, these varying in six counts as follows: 20.4 seconds; 14.4 seconds; 12.4 seconds; 15.6 seconds; 12.6 seconds; 18.4 seconds. The maximum and minimum values give respectively distances of 25.5 feet and 17.5 feet per hour. This is in fair agreement with determinations made under normal conditions out-of-doors on a level concrete walk, where one large slug, apparently travelling at the usual speed, covered 14 inches of straight course in five minutes, amounting to a rate of 14 feet an hour.

There is some indication that the mode of locomotion of the slug may be changed depending upon the character of the surface over which it moves. On ordinary

FIG. 1. PHOTOGRAPH OF THE NOCTURNAL TRAILS OF THE SLUG *Limax maximus* UPON A CONCRETE WALK, SHOWING THE SPACED SLIME SPOTS WHICH REPRESENT ITS FOOTPRINTS.

level surfaces such as soil, boards and concrete walks, the creature's usual mode of travel is such as to leave definite viscid *footprints*, so to speak, in a regular linear arrangement. This implies a slight arching of the foot at intervals, enough to keep it free from the surface over which it is traveling, except at the points of contact indicated by the slime spots of its trail. A large slug with its body fully extended 4½ to 5 inches in length may lay down 5 or 6 points of contact. Twenty-two slime spots have been laid down in a distance of 14 inches. In other trails, 18 spots in 15 inches and 12 spots in 8 inches have been counted, giving respectively, 18.8, 14.4 and 18.0 spots per linear foot.

It would appear that this is the usual mode of travel rather than an appressing of the entire length of the foot to the surface. Even when a slug travels up a vertical concrete wall, the trail is marked by spaced slime spots as when a horizontal walk is traversed. On very smooth surfaces such as glass and a glossed paint surface the body appears to be appressed throughout, and the slime trail becomes faint and more or less continuous.

It is possible that reduction in the area of contact of the foot to the surface is an economy in the direction of conserving the slime secretions, since an appreciable amount must be lost in laying it down along any trail. Probably no secretion can be discarded without some cost to the organism. Just what part the slime plays in assisting locomotion is not known, but since every wave passing along the median tread of the foot must be appressed to the fixed points localized beneath its body, it is conceivable that a concentration takes place here, more being needed, perhaps, on certain kinds of surfaces than on others.

Slugs are very restless, active creatures at night and are especially fond of moistened earth and walls where there is a drip of water. In their meandering

they readily make their way far up the trunks of trees.

The differentiated central axis of locomotion enables the creature to travel along any surface whatsoever, whether it be horizontal, vertical or even in a completely reversed position beneath a ceiling or well cover. Furthermore it can travel serenely up a fine plant stem, if it chooses, simply by contracting that portion of the foot on either side, so that it closely invests the stem, while the locomotive band or tread proper, with its nicely spaced undulations, carries the body forward on the narrow cylindrical surface. The slug's mode of locomotion is a most interesting and specialized one, with none of the slow, cumbersome, irregular squirms and laborious hitch along of portions of the trailing, rolling body in the manner of the common earth worm. The creature's onward progression is extremely smooth and graceful. A view of its pale whitish foot from beneath, closely appressed to the glass, marked with rhythmic moving waves of light and dark intervals along the median line of the tread, reveals something of impressive beauty and perfection, to offset the rather slimy, repulsive aspect of the lowly creature.

Slugs are voracious and omnivorous feeders. Not only can they be very destructive to green growing plant tissues, but they take readily to diets of bread, potatoes and other table wastes such as are placed in dishes out-of-doors for the cat or dog. I have often seen half a dozen of these creatures congregated in a pan of such food, where it has been set in an open place in a yard. It would seem that the creatures are oriented to these dishes of food by some olfactory sense, since the visual sense can be one only of generalized light sensitivity. As a matter of fact the experiments of Moquin-Tandon and the observations of L. E. Adams in England in 1897 establish this beyond question for *Limax maximus*.

The slug appears to have few enemies owing to the viscid secretions which cover its body. I have seen large ants run up to one, and as quickly rush away as soon as some of the sticky slime became fastened to their feet and antennae. While I have been studying them I have frequently seen minute flying insects and gnats alight upon them and remain helplessly captured, sticking to their slimy secretions until dead.

When all is said, the slug, which so many shun and despise, is a most interesting creature, and would well repay intensive study with respect to the physics of its unique locomotion.

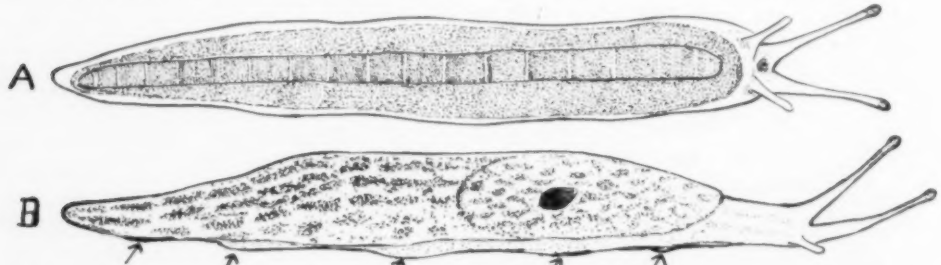


FIG. 2. A. DRAWING OF A VIEW OF THE UNDER SURFACE OF A SLUG APPRESSED AGAINST A SMOOTH PIECE OF WINDOWPANE. THE ENTIRE WIDTH OF THE APPRESSED FOOT IS SHOWN BY THE DOTTED AREA. THE MEDIAN AREA WITH CROSS STRIATIONS REPRESENTS THE LOCOMOTIVE BAND OR TREAD WITH TRAVELING WAVES, THE NARROW CRESTS OF WHICH REFLECT THE LIGHT MORE STRONGLY THAN THE DARKER INTERVENING DEPRESSIONS. B. SIDE VIEW OF CREATURE WITH NECK EXTENDED AND POINTS OF CONTACT OF THE BODY WHERE THE SLIME SPOTS ARE LAID DOWN ALONG ITS TRAIL. THESE SPOTS APPEAR TO DERIVE THEIR SLIME FROM THE NARROW MEDIAN TREAD ALONG WHICH THE WAVES RAPIDLY MOVE. ABOUT NATURAL SIZE.

THE MOUSE-EATING TARANTULA[1]

By PHIL RAU

KIRKWOOD, MO.

A VERY large specimen of tarantula, *Sericoplema rubronitens* Auss. (kindly identified by Mr. Nathan Banks) was brought into the laboratory at Barro Colorado Island in Panama on August 17, 1928, and placed in a wire insect cage.

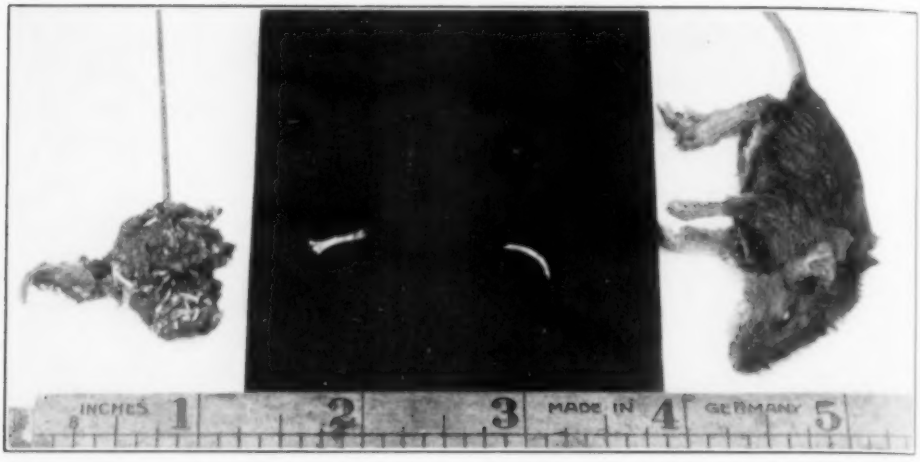
Remembering Fabre's experiment on the effect of *Lycosa* poison on a small bird, I wished to try the effect of tarantula poison on a small mammal. It so happened that Donato, the caretaker, was about to liberate several small mice which had been kept for other purposes; one of these would nicely serve my purpose.

After permitting the tarantula to fast for two days, an active mouse, whose body length measured two inches, was placed in the cage. The tarantula immediately shrank back from the mouse, and the mouse soon retired to a far corner of the cage. After ten minutes, the mouse stealthily explored the floor of the cage, discovered the hind leg of the tarantula and attempted to nibble at it. Quick as a flash the tarantula veered about and imbedded its fangs in the chin of the mouse. After a momentary struggle, the tarantula had full control of the situation, and blood oozed from the nostrils of the mouse.

The object of the experiment was to find out something of the slow effects of the poison, but in this I was disappointed, for death was immediate. For thirty minutes the victim was held in this manner; occasionally the murderer would remove the fangs for an instant, but soon replace them. Occasionally she would raise herself high on her legs with the fore part of the mouse well off the floor, and walk with it a few inches, and often while she held the mouse with her fangs she would scratch her hairy body with one or the other of her hind legs. And then finally, without removing her fangs from the victim, she carried it to the far corner of the cage and proceeded to enclose it in a silky web. She first attached a broad film of silk to the corner of the cage, and spread it into a mat on the floor by revolving slowly three times; she moved very slowly because she still held the mouse under her body with her fangs thrust into its throat. An hour and a half elapsed after the silk spinning had commenced and she had not yet succeeded in getting it fully encased. She still held the mouse with the same grip on the silken mat, often lifting it high in the air by stretching her legs and moving in circles with it. From this time there was no further effort at silk spinning, but now the fangs moved in and out and I realized that she was imbibing the juices of the limp and motionless body. The work of the poison had been deadly and almost instantaneous.

During the following five hours there was no change; the spider held the mouse quietly on the silken mat and drained the juices. She was not satisfied with fluid nutriment alone, for when I returned to the cage a little later, I found that the skin had been chewed in places and large patches of white flesh protruded. But during all this process, she never once let go of her prey. In fact, when I found it neces-

[1] Three very interesting papers by Dr. E. W. Gudger, on spiders and their vertebrate prey, have appeared in *Natural History*, 25: 261–275, 1925; 31: 58–61, 1931; and SCIENTIFIC MONTHLY, 32: 422–433, 1931.



sary to move the cage, she jumped several inches without losing her hold. The enormous strength of the spider was again demonstrated when, a little later, I blew my breath upon her through the screen, she jumped to the opposite wall and climbed its vertical surface for some distance, carrying her burden in the same way.

In the afternoon, the mouse was ill-shapen and much shrunken in size, perhaps one fifth the size that it had been when the attack occurred twelve hours before. I drove her away from it long enough to examine the remains and ascertain that not only were the body juices drained, but the flesh and some of the solider tissues were devoured by this voracious creature. I replaced it, and after twenty minutes she again took up her unsavory morsel, took it to her silky mat and resumed chewing away at the carcass. Thus she continued until midnight. The next morning, in the corner of the cage was a hard, dry mass of skin, hair and bones; this mass, stuck on a pin, is shown at the left of the figure. In twenty-four hours the mouse at the right of the illustration (this was a duplicate of the one used) was reduced to the mass of residue opposite.

One would think that a whole mouse at a meal would suffice for some time, but the next day the tarantula ate several *Orthoptera* also. Thus she was fed on insects from time to time. She was brought to St. Louis in October, and was fed during the winter; however, she ate little but remained active withal, and lived until the following April, withstanding temperature changes in our living-room, which varied from 50 to 80 during the winter.

The large, penetrating jaws are powerful, and I was not surprised when she bit a large hole in the cloth cover of the jar en route home and nearly escaped.

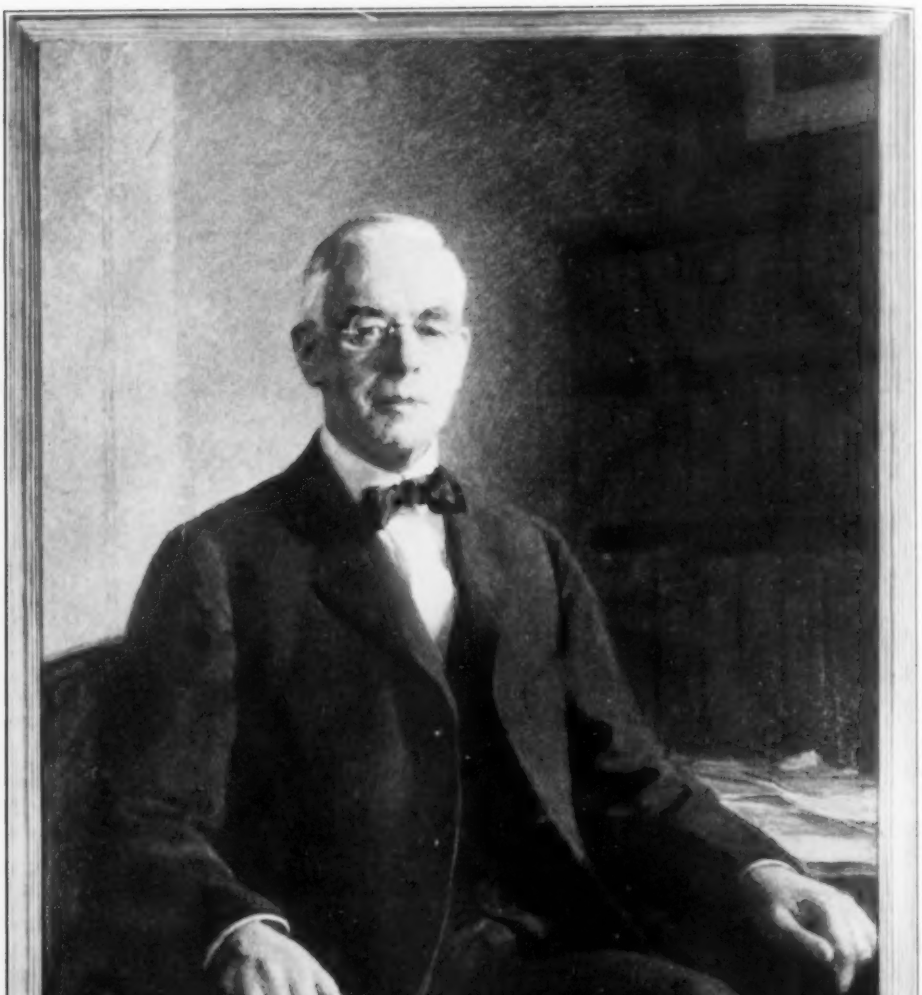
THE PROGRESS OF SCIENCE

HENRY BURCHARD FINE AND THE FINE MEMORIAL HALL

HENRY BURCHARD FINE, born in Chambersburg, Pennsylvania, September 14, 1858, was graduated bachelor of arts, with first honors, by Princeton in 1880. As an undergraduate he specialized in the classics and mathematics, and was one of the small group who discussed philosophy with Dr. McCosh and enjoyed the impulse of his invigorating mind. The year following his graduation he was fellow in experimental science and the next three years tutor in mathematics. Then he went to Leipzig to study under Klein and received his Ph.D. degree in 1885, after which he went to Berlin to be with Kronecker for a semester. He was an ardent admirer of the latter, and returned to Berlin in the summer of 1891 to study with him.

He was appointed assistant professor of mathematics at Princeton in 1885 and professor in 1889. During this period he published several papers dealing with differential equations. He was the author of four books: "The Number System of Algebra Treated Theoretically and Historically" (1891), "A College Algebra" (1905), "Coordinate Geometry" (with Henry Dallas Thompson) (1909) and "Calculus" (1927). The first of these showed the influence of Kronecker; the other three are college text-books. However, the second and fourth are a combination of text-book and treatise, were written with the greatest care, and are notable for their accuracy of statement.

Professor Fine collaborated with Professor Thomas S. Fiske in the establishment, in 1891, of the New York Mathematical Society, which became the American Mathematical Society in 1894. He was a member of the council in the



HENRY BURCHARD FINE

early years of the society and was for many years a frequent attendant at its meetings. He was president of the society in 1911 and 1912.

During Woodrow Wilson's administration at Princeton (1903–1910) Fine was dean of the faculty. These two men had been members of the editorial board of the *Princetonian* in their student days and from that time dates a life-long friendship based upon the respect which each had for the qualities of intellect and character of the other. When President Wilson went to Washington he sought the wisdom and firmness of character of his old friend for several important positions, but Fine decided to stay in Princeton. In the meantime, for the two years before President Hibben was elected, Fine administered the affairs of the university. As dean of the faculty he contributed largely to the raising of academic standards during this period. He was widely recognized as an educator of the best type and declined calls to the presidency of several institutions.

When the preceptorial system of instruction was instituted in 1905 by President Wilson, Fine seized this opportunity for laying the foundations of a department of mathematics of first rank. He was in no hurry to attain his goal. He sought young men of promise and encouraged them in their development, ever impressing them with his high ideals. They were inspired by his revealing talks about the great leaders of the latter part of the nineteenth century whom he knew, such as Klein and Kronecker, and whose great insight he appreciated. When some of his young men, such as Birkhoff, Bliss and Jeans, accepted calls elsewhere he replaced them with younger men of promise. Had not efforts been made to call away members of his group, he would have felt that his policy was not being wisely carried out. The reputation of Princeton as a center for mathematics bears abundant testimony to the wisdom of his plan and of its execution.

Dean Fine's interest in these matters was not confined to his own department. He had an important part in the choice of men in the other fields of science. In 1911 he became in letter what he was in fact—the dean of the departments of science. When it was decided in 1925 to organize a campaign for funds for the further development of research in the sciences, his was the guiding hand and he was the chairman of the committee for this purpose. Years before he had found a kindred spirit in Thomas D. Jones, of Chicago, a graduate of Princeton of the class of 1876, a man strikingly similar to Dean Fine in qualities of intellect and character. As soon as Dean Fine set forth to his friend his ideas for the future of science in Princeton, the latter offered to establish a professorship in mathematics, provided it was called the Henry Burchard Fine Professorship. This was but the beginning. Mr. Jones and his niece, Miss Gwethalyn Jones, gave three other advanced professorships and later he added a fund of five hundred thousand dollars. The fund was completed by other gifts and in particular by one million dollars from the General Education Board, and then Dean Fine was appointed chairman of the committee to advise the president on its administration.

Dean Fine died December 22, 1928, as the result of injuries received the evening previous when he was thrown from his bicycle by an automobile. During the preceding months he had discussed with the members of his department the advisability of a building for mathematics and he had come to feel that it was a necessity for the full fruition of his plans for the department. Immediately after his death Mr. Jones and his niece, who had known of these plans and hopes, announced to President Hib-

ben their desire to provide the building as a memorial to their friend.

Fine Memorial Hall, which was dedicated on October 22, 1931, adjoins and is connected with the Palmer Physical Laboratory. It is built of red brick and limestone in collegiate Gothic style and was designed by Mr. Charles Z. Klauder, of Philadelphia. It is conceived to be a house for mathematics, so that its chief features are the library, studies for members of the staff and advanced students and common rooms. In addition there are two lecture rooms, two seminar rooms and a departmental office.

The library occupies the top floor and is admirably lighted because the building has a central court. It houses the books on mathematics and physics. It is abundantly supplied with tables and chairs. It is the study for the graduate students and each of them is provided with a place for his papers and books. At each corner there is a conference room to which the students may go for discussion of their reading.

The rooms for the staff are not offices but studies. They are comfortably furnished, and as you enter one of them you feel that you are in a home and not in an office building. Some of them are paneled in American oak. Here you will find the private library of the occupant and in most instances a blackboard containing some of his work. Mathematicians take naturally to a blackboard, when they are discussing their problems or thinking them out. Other studies are allotted to advanced students in mathematics or mathematical physics of the type of national research fellows, commonwealth fellows, etc., of whom there are fourteen in residence at present; two of these men share a study.

At one end of the building, on the second floor, there is a room for the members of the staff and at the other end of the building the "Common Room" for teachers and students. These rooms are paneled in English oak, and are comfortably furnished. Every afternoon, about four-thirty, tea is served in the "Common Room." Here one finds those with whom he wishes to confer. Here develops the interest in the things common to the group. Here is the portrait by Mr. Ernest L. Ipsen, of New York, of the man whose hopes and plans are being realized.

This hall has been dedicated to the memory of Henry Burchard Fine. Its solidity of structure, its dignity, its refinement and its sense of calm symbolize the man.

L. P. Eisenhart

THE LIBRARY IN FINE MEMORIAL HALL

PRESENTATION OF MEDALS BY THE AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

ACHIEVEMENT in the mining of copper ores and in the smelting and refining of copper was recognized at the annual meeting of the American Institute of Mining and Metallurgical Engineers. The William Lawrence Saunders Medal for distinguished achievement in mining was awarded to Francis W. Maclennan, general manager for the Miami Copper Company; and the James Douglas Medal for distinguished achievement in nonferrous metallurgy was awarded to William H. Peirce, president of the Baltimore Copper Smelting & Refining Company and vice-president of the American Smelting & Refining Company.

Mr. Maclennan is a native of Canada and a graduate of McGill University. He has practiced his profession in Canada, Peru and the United States. In 1913 he became mine superintendent for the Miami Copper Company, and since 1919 he has served as general manager. The particular work for which he was cited is the development of a method of mining low-grade copper ore by block caving so efficiently that the over-all cost has been as low as 36 cents per ton of ore. A measure of the success of the operation is the mining of 21 tons of ore per man-shift, a figure never before equalled for underground mining. Previous medalists have been D. W. Brunton, Herbert Hoover, John Hays Hammond and Daniel C. Jackling.

Mr. Peirce, born in Baltimore, was trained as a mechanical engineer. He early entered the copper smelting business and was remarkably successful in the design and improvement of machines and apparatus for the smelting and refining of copper. He has made notable contributions to these arts, his name being known throughout the industry as the co-inventor of the Smith-Peirce basic converter for the production of blister copper from matte.

THE PRESIDENT OF THE INSTITUTE AND THE TWO MEDALISTS
FRANCIS W. MACLENNAN, WM. H. BASSETT AND WILLIAM H. PEIRCE.

SAMUEL WESLEY STRATTON

WHO DIED ON OCTOBER 17 IN HIS SEVENTIETH YEAR. HE WAS DIRECTOR OF THE BUREAU OF STANDARDS FROM 1901 TO 1923, AND THEN BECAME PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY UNTIL 1930, WHEN HE WAS MADE CHAIRMAN OF THE CORPORATION OF THE INSTITUTE.

THE AWARD OF THE RESEARCH CORPORATION PRIZES

For effective scientific research, undertaken without thought of personal pecuniary benefit, two scientists—one American, the other Swedish—have each gained the Research Corporation prize of $2,500. It was awarded through the Smithsonian Institution. The men are Dr. Andrew Ellicott Douglass, director of Steward Observatory of the University of Arizona, and Dr. Ernst Antevs, of the University of Stockholm. Each will likewise receive the Research Corporation plaque for their outstanding contributions to science.

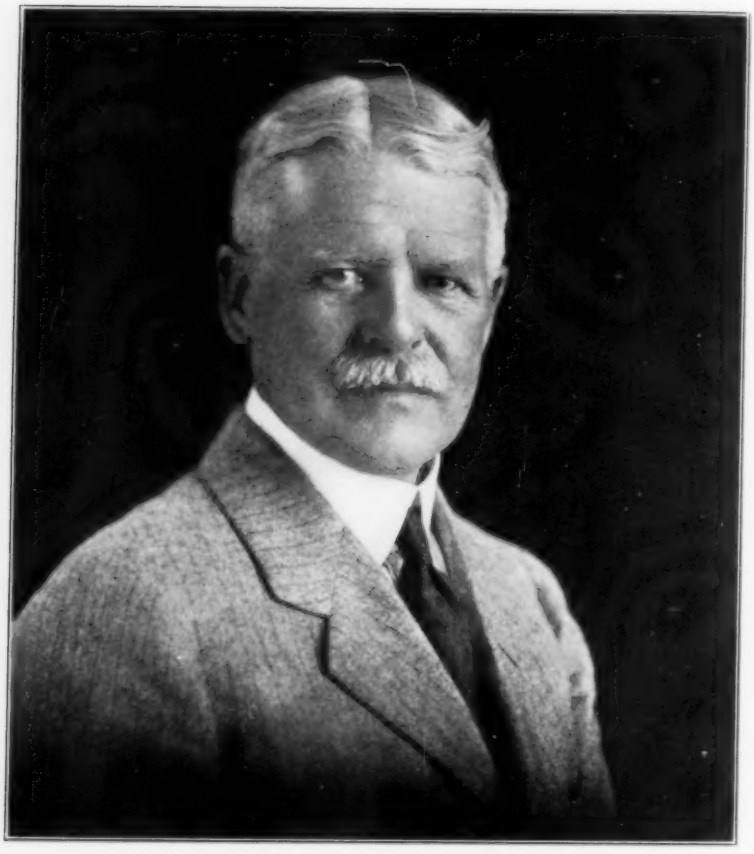
Though in no way related, the achievements of the two prize winners are curiously similar in results and in method; they have succeeded in dating the prehistoric past of the earth by what are unquestionably the two most original and the only exact methods yet developed, and they have reconstructed a picture of the changes in the earth's weather year by year for the thousands of years that they have been able to date.

Dr. Douglass, who is primarily a physicist and an astronomer, used as his chronometer the rings that mark the annual growth of trees. Living amidst the pine forests in the bracing climate of northern Arizona, he was led to think of the connection between climate and tree growth. In 1901 he began collecting records of tree growths as pictured by annual rings in cross-sections of the trunks. A comparison of some 10,000 such records with records of precipitation in northern Arizona showed that the ring formed by a tree each year varies in width in direct proportion to the amount of rainfall. Here, evidently, was an almost infallible record of weather and climate of the region in which the natural chronometer grows. Trees in the same climatic area would show similar response to the same weather conditions in their annual rings; that is, a scale of the proportional widths of the annual rings of one tree for a definite series of years would approximately fit any other tree in the same area for the same series of years. Dr. Douglass found this to be so for trees over fairly wide areas, and this rendered possible their dating on a common scale with practical certainty.

Thanks to this fact, Dr. Douglass has been able to extend back tree growth records in the giant sequoias of California for 3,000 years. He has also connected all the links in the tree growth chain from the present time backward without a gap to 700 A.D. That is, he has created an unbroken annual calendar for that period. Unexpected benefits have resulted from the development of this perfect time scale. Thus, by a study of timbers taken from pueblos built by the prehistoric Indians, Dr. Douglass has been able to give exact dates to events in their history, such as the building of Pueblo Bonito, as far back as the eighth century. There is no reason to suppose that the application of the method can not be carried much farther back in human history.

However, the major fruits of Dr. Douglass' achievements are probably the light they have cast on the past climate of the earth and on the correspondence between weather and solar activity. Dr. Douglass found that trees grown in the wet climates of northern Europe give admirable records of sun-spot numbers; he found several cycles in climate to be multiples or submultiples of the eleven-year sun-spot cycle. This shows indisputably that solar variation exerts a profound influence on weather.

Dr. Antevs used the laminated clay deposits called varves as his time-piece and has traced a series of clay layers up the Connecticut Valley of New England, which mark approximately 4,000 successive years. Dr. Antevs is a pupil of Baron de Geer, student of glacial chro-



DR. ANDREW E. DOUGLASS

nology and founder of the Stockholm Geochronological Institute, and to de Geer belongs the credit for the use of varves as time-pieces of glacial activity.

That nature should have left, and man interpreted, so detailed a record of yearly climates in the soil is no less amazing than the record and interpretation of tree rings. Varves are thin layers of very fine clay which lie one on top of another so that a cross-section of them exposed looks like zebra stripes on the earth. They record the annual erosive influence of melting glacial water. In the Ice Age glaciers of great thickness covered the whole of northern Europe and America as they now cover the peaks of the Alps. When for some reason the earth began receiving more heat from the sun, the latter was able each summer to melt more than the accumulations of the previous winter's snow and ice, and the glaciers began slowly to disappear, retreating to the north and to high altitudes. The melting ice passed through glacial fissures and issued in streams at the bottom of the glaciers, bearing mud and gravel. The finer sediment would be carried farthest—into glacial lakes, where, in the quiet of the following winter, it would settle down into a layer or varve, superposed on that of the previous year. Since the finest particles would stay suspended the longest time, each varve would vary from coarse at the bottom to fine at the top, so

DR. ERNST ANTEVS

that there would be a visible demarcation corresponding to each successive year. Furthermore, the varves varied in thickness from year to year, just as do tree rings, and for comparable reasons. That is, a thick ring would mean a greater supply of water-carrying sediment, and that would mean a hotter summer. In consequence, the thickness of the varves would represent in some measure the power of the sun rays during the summer. As the varves often accumulated to many feet in depth, and as those formed in one lake can be correlated with those formed in another, they constitute a record of thousands of years of solar activity.

Dr. Antevs helped Baron de Geer and other assistants to work out the "Swedish time scale," believed to give approximately in years the time elapsed since the culmination in Sweden of the last Ice Age. In 1920 Antevs accompanied de Geer to America to make a study of American varves with a view to correlating in time American with European glaciation. Antevs has remained in America to become the leading authority on North American glaciation. Besides tracing out a series of clay layers which mark approximately 4,000 successive years up the Connecticut Valley, he has worked out successive positions of the receding ice border, and assigned to each deposit its proper date with reference to a certain point in the glacial

period. The measuring of clay layers has been only a small part of his work. As Dr. Goldthwaite, of Dartmouth, says:

> Equally at home in physiography, Pleistocene botany and zoology, and eager in his study of climates of the past, he has never lost sight of the large geologic and geographic problems, such as the registration of changes of temperature and of rainfall by sediments, by tree rings, and by migrations of plants and animals, the nature and cause of crustal warping during the withdrawal of the ice, the emergence and submergence of the coast and of the interior lowlands as a result both of crustal movements and of the exchange of water between ocean and glacier.

The awards to Dr. Douglass and Dr. Antevs are the fourth and fifth of their kind made by the Research Corporation. The first, in 1925, went to Dr. John J. Abel, of the Johns Hopkins University, for his work on ductless glands, animal tissues and fluids. The second, in 1929, went to Dr. Werner Heisenberg, of the University of Leipzig, for his contribution to matrix mechanics and for his exposition of the principle of indeterminance; and the third, also in 1929, to Dr. Bergen Davis, of Columbia University, for the contribution of the Davis double x-ray spectrometer and other brilliant achievements in the field of atomic physics.

The Research Corporation is probably the only organization of its kind in existence. It sprang from the desire of a scientist to have the fruit of his scientific labors capitalized for the promotion of research. In 1911, Dr. Frederick G. Cottrell, then chief physical chemist, later director of the U. S. Bureau of Mines, and his associates offered their invention for the electrical precipitation of suspended particles to the Smithsonian Institution, for the benefit of science. As the institution ec
undertake the development
so likely to have commerci
complications, Dr. Charles
then secretary of the Smit
dertook with Dr. Cottrell
aid of public-spirited men
City to organize a non-profi
poration for the development o. the pat-
ents, and in 1912 the Resea orpora-
tion was formed.

Its purposes are to acquir inventions and patents and make them more available in the arts and indu ies, while using them as a source of income, and second, to apply all profits from such use to the advancement of technical and scientific investigation and experimentation. The Research Corporation has succeeded financially so that it has built up a reserve and given large funds to scientific work. Among grants made by the corporation are several to the Smithsonian Institution for work on solar radiation and its influence on plants and animals; to the Kaiser Wilhelm Institute for Medical Research, at Heidelberg, to carry on cancer research, to the International Auxiliary Language Association for linguistic research, to Harvard University, Columbia University, Leland Stanford Junior University, Pennsylvania State College and the Stevens Institute of Technology, in support of various projects. A grant was made to the National Research Council to assist in the publication of one of the volumes of the "International Critical Tables." The last grant has been made to the University of California to make possible the installation of an eighty-five ton magnet, through which it is hoped to produce twenty-five million volt protons.

INDEX

NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS

The New President of the Na- ..y of Sciences, 87
.. L., Belgian Congo Sanctuaries,

.. Biological Opportunities in

ALLARD, H. .. Locomotion of the Slug, 559
ALLEN, W. F Units of Environment, 307
Alligator, .. Ways of, A. M. REESE, 321
American .. ciation for the Advancement of Science, Pasadena Meeting, E. C. WATSON, 187 · A. H. CLARK, 187
ANTHONY, H. E., Vernay-Faunthorpe Hall of South Asia Mammals, 279
tom, What It Looks Like, A. H. COMPTON, 550
AVERILL, L. .., Childhood in the Machine Age, 522

Backward School Children, C. W. STILES, 362
BECKWITH, T. D., Dental Caries, 267
Beijerinck, Martinus Willem, S. A. WAKSMAN, 285; Portrait, 286, 287
Belgian Congo Sanctuaries, M. L. J. AKELEY, 289
BENEDICT, F. G., Weight Reduction, 264
BISHOPP, F. C., How Insects Affect Our Health and Comfort, 443
Blood Groups, Heredity of, W. V. LAMBERT, 37
BOAS, Franz, Portrait, 184
BRAGG, W. H., Michael Faraday, 481
BRASCH, F. E., Royal Society of London, 336, 448
Brighter Days Ahead, R. E. DANFORTH, 318
BROWN, F. C., Work of Faraday and Henry, 473
BROWN, R. M., Water Supply of Cities, 135
Butterfly, Extirpation of One by Another, A. H. CLARK, 173

Caecapon, at the Head of, J. G. NEEDHAM and P. D. STRAUSBAUGH, 80
Calendar Reform, H. C. WARREN, 440
Campbell, W. W., Portrait, 88
Capper Award, A. CAPPER, 192; and L. O. Howard, G. W. HERRICK, 189
CARLSON, A. J., Hunger, 77
Cattell, J. McKeen, Portrait, 184
Charting the Sea and Air, W. R. GHERARDI, 168
Childhood in the Machine Age, L. A. AVERILL, 522
CLARK, A. H., Extirpation of One Butterfly by Another, 173; Pasadena Meeting of the American Association, 187
Columbia University, New Residence for Medical Students at, H. L. NORRIS, 380
COMPTON, A. H., What the Atom Looks Like, 550
COUCH, J. F., Poison Ivy, 359

DANFORTH, R. E., Brighter Days Ahead, 318
Dental Caries, T. D. BECKWITH, 267
DICE, L. R., Relation of Mammalian Distribution to Vegetation Types, 312
Dinosaur Skeleton at the Peabody Museum, 382
Disease, Cause and Prevention, J. E. GREAVES, 428
Drought, Biological Effects of, H. J. VAN CLEAVE, 301

EDDY, P. F., Insects in English Poetry, 53, 148
Educational Plant, Modern, T. S. HARDING, 539
Egg, Development of, C. G. HARTMAN, 17; C. W. METZ, 117
EISENHART, L. P., Henry Burchard Fine and the Fine Memorial Hall, 565
ELLMS, J. W., Water Purification and Sewage Disposal on the Great Lakes, 423
Engineers, Mining and Metallurgical, Institute of, Presentation of Medals, 567

Faraday, and Henry, Work of, F. C. BROWN, 473; Michael, W. H. BRAGG, 481; Portrait, 474
Farrand, Max, Portrait, 184
Fine, Henry Burchard, and the Fine Memorial Hall, L. P. EISENHART, 565
FLEMING, J. A., The Magnetism of the Earth, 74; Jubilee International Polar Year, 375
Flowers, Wild, Save, E. T. WHERRY, 535
Fog, Control of, A. MCADIE, 28
Franklin, Benjamin, Portrait, 465
Fred, E. B., Portrait, 95

GHERARDI, W. R., Charting the Sea and Air, 168
GREAVES, J. E., Disease, Cause and Prevention, 428
GUDGER, E. W., and W. H. HOFFMANN, A Shark Encircled with a Rubber Automobile Tire, 275

Hale, George E., Portrait, 180
HALL, E. H., James Clerk Maxwell, 500
HALL, M. C., Glorification of Parasitism, 45
HARDING, T. S., Modern Educational Plant, 539
HARTMAN, C. G., Development of the Egg, 17
HELLWEG, F., New Reflector Telescope of the U. S. Naval Observatory, 283
Henry, Joseph, E. W. STONE, 212; and Faraday, Work of, F. C. BROWN, 473; Portrait, 220, 222, 478
HERRE, A. W., European and American Policies in the Pacific Colonies, 434
HERRICK, G. W., Dr. L. O. Howard and the Capper Award, 189
HORVATH, A. A., Soya Flour, 251
HOUGH, W., Culture and the Racial Matrix, 164
Howard, L. O., and the Capper Award, G. W. HERRICK, 189; Portrait, 190
HUBBARD, H. D., Romance of Measurement, 356
Hunger, A. J. CARLSON, 77

Insects, in English Poetry, P. F. EDDY, 53, 148; and Health, F. C. BISHOPP, 443
Ivy, Poison, J. F. COUCH, 359

JEANS, J. H., Modern Theories of Universe, 12
Jeans, Sir James Hopwood, in New York, Greetings of Amer. Physical Soc., W. F. G. SWANN, 5; Introductory Remarks, M. I. PUPIN, 10;

Speakers at Dinner in Honor of, Portraits, 86
JEFFRIES, Z., The Plasticity of Metals, 235
Jordan, David Starr, R. L. WILBUR, 471; Portrait, 470

Kemble, E. C., Portrait, 91
Knopf, A., Portrait, 93

LAMBERT, W. V., Heredity of Blood Groups, 37
LEHMAN, H. C., and P. A. WITTY, Scientific Eminence and Church Membership, 544
LODGE, O., Wireless Communication, 512

MCADIE, A., The Control of Fog, 28
MACDOUGAL, D. T., The Thirst of Plants, 171
MACK, E., JR., Size and Shape of Molecules, 365
Magnetism of the Earth, J. A. FLEMING, 74
Mammalian Distribution, Relation to Vegetation Types, L. R. DICE, 312
Mammals, South Asiatic, Vernay-Faunthorpe Hall of, H. E. ANTHONY, 279
Man's Development, O. RIDDLE, 555
Mathematical Weakness of the Early Civilizations, G. A. MILLER, 419
Mathematics of China, D. E. SMITH, 244
Maxwell, James Clerk, E. H. HALL, 500
Measurement, Romance of, H. D. HUBBARD, 356
MEGGERS, W. F., Rhenium, 413
MERRIAM, J. C., The Unity of Nature as Illustrated by the Grand Canyon, 227
Metals, Our, N. SABSAY, 142; The Plasticity of, Z. JEFFRIES, 235
METZ, C. W., Development of the Egg, 117
MILLER, G. A., The Mathematical Weakness of the Early Civilizations, 419
MILLER, J. A., Distances of Nearer Stars, 552
Millikan, Robert A., Portrait, 180, 184
Molecules, Size and Shape of, E. MACK, JR., 365
Moore, R. L., Portrait, 91
Morgan, John, Portrait, 466
Morgan, Thomas Hunt, Portrait, 184
Muller, H. J., Portrait, 93

Naval Observatory, U. S., New Reflector Telescope, F. HELLWEG, 283
NEEDHAM, J. G., and P. D. STRAUSBAUGH, At the Head of the Cacapon, 80
NORRIS, H. L., New Residence for Medical Students at Columbia University, 380
Noyes, Arthur A., Portrait, 180

Pacific Colonies, European and American Policies in, A. W. HERRE, 434
Parasitism, Glorification of, M. C. HALL, 45
PARK, W. H., Epidemic Poliomyelitis, 261
Peking Man, G. E. SMITH, 193
Photomicrography with Ultra-violet Light, A. P. H. TRIVELLI, 175
Physical Society of America, Greetings to Sir James Hopwood Jeans, W. F. G. SWANN, 5
Plants, Thirst of, D. T. MACDOUGAL, 171
Polar Year, Jubilee, J. A. FLEMING, 375
Poliomyelitis, Epidemic, W. H. PARK, 261
Primate, Man as, A. H. SCHULTZ, 385
Progress of Science, 86, 181, 279, 375, 470, 565
PUPIN, M. I., Introductory Remarks to Greetings to Sir James Hopwood Jeans, 10
Pupin, M. I., Portrait, 86

Racial Matrix and Culture, W. HOUGH, 161
RAU, P., The Mouse-eating Tarantula, 563
REESE, A. M., The Ways of the Alligator, 221
Research Corporation Prizes, 571
Rhenium, W. F. MEGGERS, 413
RIDDLE, O., Man's Development, 555
Rittenhouse, David, Portrait, 469
Royal Society of London and Its Influence upon Scientific Thought in the American Colonies, F. E. BRASCH, 336, 448

SABSAY, N., Whence Our Metals?, 142
SCHULTZ, A. H., Man as a Primate, 385
Science Service Radio Talks, 74, 164, 261, 356, 443, 550
Sciences, National Academy of, New President, R. G. AITKEN, 87; Spring Meeting, F. E. WRIGHT, 91; Portraits of Members, 90, 92, 94
Scientific Eminence and Church Membership, H. C. LEHMAN and P. A. WITTY, 544
Shark Encircled with Rubber Tire, E. W. GUDGER and W. H. HOFFMANN, 275
Siam, Biological Opportunities in, G. ALEXANDER, 97
Slug, The Locomotion of, H. A. ALLARD, 559
SMITH, D. E., Mathematics of China, 244
SMITH, G. E., Sinanthropus—Peking Man, 193
Soya Flour, A. A. HORVATH, 251
Stars, Nearer, Distances of, J. A. MILLER, 552
STILES, C. W., Backward School Children, 362
STONE, E. W., Joseph Henry, 212
Stratton, S. W., Portrait, 567
Streeter, G. L., Portrait, 93
SWANN, W. F. G., Greetings of American Physical Society to Sir James Hopwood Jeans, 5
Swann, W. F. G., Portrait, 86

Tarantula, The Mouse-eating, P. RAU, 563
Tide and Sea Beaches, P. C. WHITNEY, 445
TRIVELLI, A. P. H., Photomicrography with Ultra-violet Light, 175

Universe, Modern Theories of, J. H. JEANS, 12

VAN CLEAVE, H. J., Biological Effects of Drought, 301

WAKSMAN, S. A., Martinus Willem Beijerinck, 285
WARREN, H. C., Psychological Aspects of Calendar Reform, 440
Washburn, M. F., Portrait, 95
Water, Supply of Cities in the United States, R. M. BROWN, 135; Purification and Sewage Disposal on Great Lakes, J. W. ELLMS, 423
WATSON, E. C., Pasadena Meeting of the American Association, 181
Weight Reduction, F. G. BENEDICT, 264
WHERRY, E. T., Save Our Wild Flowers, 535
WHITNEY, P. C., Sea Beaches and the Tide, 445
WILBUR, R. L., David Starr Jordan, 470
Winthrop, John, Portrait, 468
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Wireless Communication, O. LODGE, 512
WRIGHT, F. E., Spring Meeting of the National Academy of Sciences, 91

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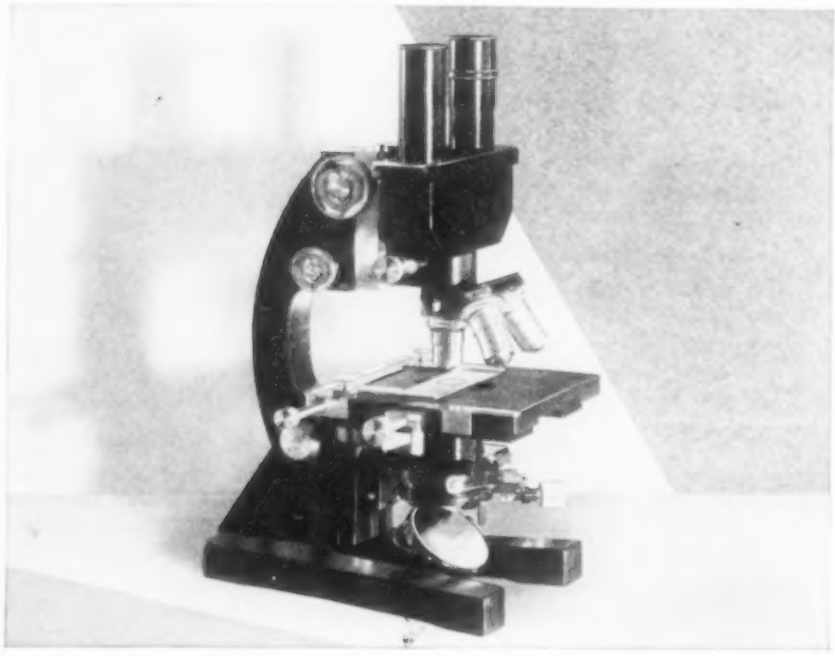

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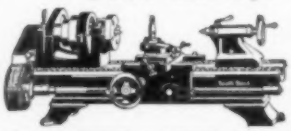

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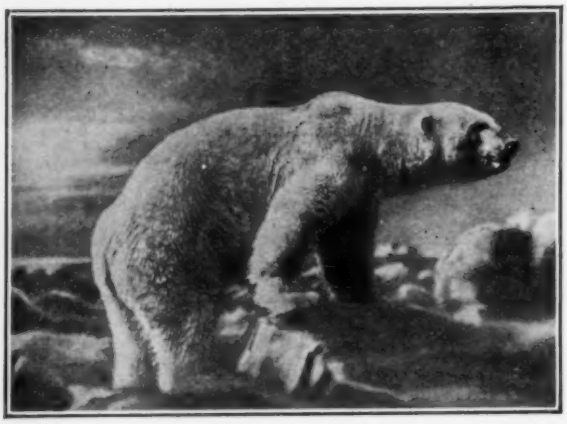

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